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TUCSON WASTEWATER RECLAMATION PROJECT

Paul Beermann, et al

Tucson Water and Sewers Department
Tucson, Arizona

July 1966

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PLANNING & RESEARCH SECTION
WATER & SEWERS DEPARTMENT
CITY OF TUCSON

FIRST ANNUAL REPORT
JUNE 1965 - JUNE 1966

TUCSON WASTEWATER RECLAMATION PROJECT

at

TUCSON, ARIZONA

PAUL BEERMANN
PROJECT DIRECTOR

Details of illustrations in
this document may be better
studied on microfiche.

JULY 1966

PREPARED FOR
THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
WASHINGTON, D.C.

THIS PROJECT WAS SUPPORTED, IN PART, BY DEMONSTRATION GRANT # WPD 108-01-65 FROM THE RESEARCH AND TRAINING GRANT PROGRAM, FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

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CITY OF TUCSON

WATER AND SEWAGE SYSTEMS
Room 208, Mayer-Alameda Bldg.
110 E. Alameda Street
Tucson, Arizona 85701

July 29, 1966

Mr. Harry A. Faber, Chief
Research and Training Grant Program
Federal Water Pollution Control Administration
U. S. Department of the Interior
633 Indiana Avenue, N. W.
Washington, D. C. 20203

Dear Mr. Faber:

In compliance with Water Pollution Control Demonstration Project Grant No. WPD-108-01-65, dated June 10, 1965, awarded to the City of Tucson, Arizona, Department of Water and Sewers, we are pleased to submit herewith the First Annual Report of the Tucson Wastewater Reclamation Project. This report contains area maps, tables, graphs, design drawings, forms and other pertinent data, along with a summary of the work produced during the first year of the grant period. This grant has been extended for a period of one additional year, and therefore this report is, in reality, a yearly interim progress report.

We wish to thank you for your continuing cooperation and financial support in our wastewater reclamation effort.

Respectfully yours,

Paul Beermann
Project Director

PB/ged/b

FIRST ANNUAL REPORT
TUCSON WASTEWATER RECLAMATION PROJECT

by

GORDON EMERSON DAVIS, C.E.
acting project engineer

and

JOHN FRANK STAFFORD
project chemist

et al.

JULY 1966

TECHNICAL PLANNING COMMITTEE:

MR. EDMUND GARTHE - CHAIRMAN
DR. KENNETH F. WERTMAN
PROF. QUENTIN M. MEES
DR. FREDRICK J. BRADY
MR. GERRY HAUER
MR. HARVEY F. LUDWIG
DR. WILLIAM McCONNELL
MR. PAUL BEERMANN

PLANNING & RESEARCH SECTION
WATER AND SEWERS DEPARTMENT
CITY OF TUCSON
CO-OPERATING WITH
DEPT. OF CIVIL ENGINEERING, UNIV. OF ARIZONA
DEPT. OF MICROBIOLOGY & MEDICAL TECHNOLOGY, UNIV. OF ARIZONA

SUMMARY

Work commenced on this project immediately following notification of approval and funding and has continued apace throughout the year covered by this report (June 15, 1965 to June 14, 1966).

The project scope required the participation of the University of Arizona, Departments of Civil Engineering and Microbiology and Medical Technology, with the City of Tucson, the grantee.

The responsibilities of the Planning and Research Section of the City of Tucson Water and Sewers Department included design and supervision of construction of the pilot filter system; office, field, and laboratory investigation of the geology, hydrology, well construction and chemical quality of waters within the project area; formulation, production and execution of plans, maps, and forms for the construction of the pilot filter system, the identification of project area wells and related features; and the compilation and reporting of all data relative to the project. The Department of Civil Engineering at the University performed all bacteriological and CCE tests, assisted in the well inventory, and provided technical advice to the filter construction. The Microbiology and Medical Technology Department advised on project activities and conducted the virus test program. The technical committee reviewed, discussed, and acted on all project plans, proposals, and technical aspects, as required.

The phases of the TWRP may be simply divided into (1) the construction, operation and monitoring of a tertiary treatment facility in the form of a pilot filter and (2) the accumulation and evaluation of analytical,

physical, and documentary evidence from the study of wells within the outlined project area. At this writing, the pilot filter has gone through the phases of design and construction, and we are embarking upon a rigorous program of sampling of the filter points and discharge after the application of activated sludge effluent from the Tucson Wastewater Treatment Plant (TWTP).

The analytical, physical, and documentary phase of the project has accumulated large amounts of data which have been analyzed and are included elsewhere in the report. This phase will continue regularly in the coming years in an effort to thoroughly correlate the future results with those obtained thus far.

To date, project activities have given many and varied results. Characteristic patterns of nitrate concentrations are delineated and plotted on maps of the project area. Measurable amounts of Alkyl Benzene Sulfonate (A.B.S.) were found in well waters near the main channel of the Santa Cruz River. Bacteriological contamination was evidenced on an irregular basis, and many areas that indicated fecal contamination were neither near the Santa Cruz River nor within an effluent irrigated land mass.

Routine monitoring of the Tucson Wastewater Treatment Plant during the period 1951 to the present resulted in characterization of plant flow volumes, mineral composition, biologic activity, effluent character, and diurnal variation of the preceding items. Intensification of this program during 1965-66 allowed for the proper selection of effluent material (activated sludge) to be applied to the pilot filter, as well as the time and place for collecting the effluent for distribution.

Further, a historical evaluation of flow volumes, mineralogy, and nitrogenous components in TWTP influent and effluent made possible the estimation of Santa Cruz River recharge for a period of 25 years, in the project area, along with an evaluation of the effect of transferring sewage effluent four (4) miles downstream from the present TWTP facility and using said effluent to irrigate previously fresh well-water irrigated lands.

In sampling the wells within the project area, much was learned about well construction, sanitary conditions, and use of wells that was not previously available to local government agencies. This data was committed to evaluation forms and analyzed. The well maps of the area were updated and the results used to consider or eliminate some wells for future examination.

Last, but far from least, the Pilot Filter Project was completed, and at this writing, is operating in a conditioning phase recommended by the Project's Technical Committee. Disturbances in construction resulted from heavy rains in November of 1965 and held up activity for a short period. Every bit of filter media added to the filter excavation was on the job quality controlled, and the data from permeability studies in progress during construction were recorded. Progress on visible construction was documented by a series of photographs taken at regular intervals, and some of this documentary is supplied within the report.

The quality of the water in its path through this vertical-horizontal filter is being monitored through well sites at intervals throughout the filter, as well as at the influent and effluent sides. Bacteriological and virological identifications are proceeding on a regular sampling basis twice weekly in this conditioning phase.

It may be concluded at this time that the project is proceeding well, and further activity reports await the second year quarterly report time.

TABLE OF CONTENTS

Item		Page
LETTER OF TRANSMITTAL		
FRONTISPIECE		
SUMMARY		i
TABLE OF CONTENTS		v
LIST OF TABLES AND PLATES		vii
LIST OF FIGURES		viii
CHAPTER I - INTRODUCTION		I-1
1.01	Authorization	I-1
1.02	Purpose	I-2
1.03	Scope	I-2
1.04	Personnel	I-4
1.05	Acknowledgements	I-5
	Technical Committee	I-6
CHAPTER II - DESCRIPTION OF PROJECT AREA		II-1
2.01	Introduction	II-1
2.02	Geohydrology	II-2
CHAPTER III - TUCSON WASTEWATER TREATMENT PLANT		III-1
3.01	Introduction	III-1
3.02	Quantity of Wastewater	III-1
3.03	Quality of Wastewater	III-2
CHAPTER IV - EFFLUENT RECHARGE AREA		IV-1
4.01	Introduction	IV-1
4.02	Data Acquisition	IV-1

Item		Page
4.03	Chemical Quality of Well Waters	IV-3
4.04	Effect of Effluent Irrigation and Recharge	IV-4
4.05	Bacteriology of Wells	IV-6
4.06	Microbiology and Virology of Wells	IV-10
CHAPTER V - PILOT FILTER		V-1
5.01	Introduction	V-1
5.02	Physio-Biochemical Activity	V-2
5.03	Pre-Construction Investigations	V-5
5.04	Design Specifications	V-7
5.05	Construction	V-7
5.06	Plan for Operation	V-9
5.07	Plan for Investigation	V-11
5.08	General Considerations	V-12
CHAPTER VI - MICROBIOLOGY AND VIROLOGY		VI-1
6.01	Methodology	VI-1
6.02	Results	VI-4
APPENDIX A - SAMPLE PROJECT FORMS (in pocket)		VII-I
APPENDIX B - SUMMARIZED STATEMENT OF EXPENDITURES - 15 June 1965 to 14 June 1966		VII-2

LIST OF TABLES

Number	Following Page
1. Historic: Distribution of Effluent 1940-1965	III - 2
2. Analysis: 20 IV 66	III - 2

LIST OF PLATES

Number	Following Page
1. Filter Sampling Wells in Place & Plastic Placement	V - 8
2. Filter Media Build-Up and Mixing	V - 8
3. PVC Line (Well) Installation - Spreading Basin Completed	V - 8
4. Collection Trough (Partial Completion) - Pumping	V - 8
5. Fence Diagram (Geologic)	Pocket
6. Pilot Filter (As-Built)	Pocket
7. Pilot Filter (As-Built) Elevations Sampling Wells No. 1, 2, and 3	Pocket

LIST OF FIGURES

Number		Following Page
1.	Project Area and Surface Geology Map	II - 1
2.	Historic Distribution of Effluent 1940-1965	III - 2
3.	Schematic Distribution of Effluent 1940-1965	III - 2
4.	Activated Sludge Effluent - Mineral Analysis 1951-1965	III - 3
5.	Activated Sludge Effluent - Organic Analysis 1951-1965	III - 3
6.	Activated Sludge Effluent - B.O.D., etc. 1951-1965	III - 3
7.	Activated Sludge Effluent - B.O.D., etc. 1965-1966	III - 3
8.	Quality Comparison - Project Wells	IV - 5
9.	Chemical Quality Map	IV - 5
10.	Nitrate Content in Well Waters	IV - 5
11.	A.B.S. Distribution in Well Waters	IV - 5
12.	Bacteriological Contamination Map	IV - 6
13.	Mineral Analyses Plot 1966	V - 10
14.	Treatment Plant Flow Diagram	VI - 4
15.	Permeability Test Trough	V - 6
16.	Pilot Filter System	V - 7
17.	Construction Schedule	V - 8

CHAPTER 1

INTRODUCTION

1.01 AUTHORIZATION

The chemical, bacteriological, virological research and filter construction work in the following report was authorized in WPD-108-01-65, dated June 10, 1965, between the City of Tucson, in cooperation with the University of Arizona departments of Civil Engineering and Mircrobiology, and the Department of Health, Education, and Welfare, United States Public Health Service.

During the course of the aforementioned grant period, a change in sponsorship from the original grantor to the United States Department of the Interior occurred, and our correspondence has so reflected this change. On June 21, 1965, by act of the Mayor and Council, Resolution No. 6218 was passed which provided for the acceptance of funds from the U. S. Government Project entitled "Tucson Wastewater Reclamation Study"; and authorized the grantee to contract with the Board of Regents of the Universities and State College of Arizona for co-operation in contribution of funds or services for the furtherance of the project.

The University of Arizona Department of Civil Engineering was to provide the bacteriological and the Department of Microbiology and Medical Technology the virological capability for the project.

A second formal agreement was accomplished between the City of Tucson and Engineering-Science, Inc., of Arcadia, California, for the consulting services of Mr. Harvey Ludwig (represented by Mr. Don Anderson) who is a member of the Technical Planning Committee composed of local health officials and other specialists.

Informal working agreements between the City of Tucson and (1) Arizona State Department of Health, (2) Pima County Health Department, (3) Arizona State Department of Game and Fish, and (4) University of Arizona Cooperative Fisheries Unit, were consumated to aid the committee.

1.02 PURPOSE:

→ The purpose of the report is:

To demonstrate the chemical, microbiological, and virological safety and the aesthetic acceptability of including renovated wastewater as a dependable and substantial portion of the future water supply for Metropolitan Tucson. As stated in the Grant Application, the objectives of this demonstration project are as follows:

a. To demonstrate the feasibility of upgrading secondary Sewage effluent by horizontal-flow sand filtration. The objective is to renovate a wastewater that is satisfactory for recreational purposes such as fishing, boating and swimming, and ultimately for drinking water purposes following treatment.

b. To construct and operate a pilot plant scale sand filtration plant for the purpose of establishing full scale design characteristics. (Phase One)

c. To demonstrate the safety of renovated wastewater use by conducting a series of microbiological, virological and other tests in the pilot plant and by systematic sampling of ground water in areas now recharged with wastewater. (Phase Two)

1.03 SCOPE

This project was organized to include but not necessarily be limited to the following:

a. To establish a City-County-State-University technical committee for planning and guidance of demonstration activities.

b. To study municipal sewage treatment plant effluent as a supplementary source of water supply.

c. To construct and operate a pilot scale spreading basin - horizontal flow filtration-pond facility.

d. To establish design factors for a full scale recreation - recharge area.

e. To demonstrate safety of using renovated wastewater by conducting a series of microbiological, physical and chemical tests.

f. To systematically sample and analyze ground water in areas now recharged with wastewater.

g. To ascertain most economic, safe, and feasible combination of the above (or any required special additional) wastewater processing acceptable to the public for supplementing ground water resources and for direct drinking water supply uses.

h. To provide answers to the many questions raised by contemplated wastewater re-use including:

1. What method of wastewater treatment, beyond conventional treatment, is most feasible in the Tucson area?
2. What quality of treated wastewater can be achieved consistently and at what cost?
3. Is it advisable to re-cycle the treated wastewater through a groundwater basin? If so, what method of re-cycling should be used?
4. Can treated wastewater be blended with the present water supply?
5. What safeguards are necessary to protect public health and assure quality of water?
6. How do the projected costs of re-cycling compare with those of imported surface water supply?
7. What type of public information program can be used to gain public acceptance?

1.04 PERSONNEL

The personnel who have been actively engaged in the project objectives are listed below, and their contributions and scientific assistance are greatfully acknowledged:

Project Position	
Project Director	Paul Beermann, Director, Water & Sewage Systems City of Tucson
Sanitary Engineer	Quentin M. Mees, Professor Department of Civil Engineering, University of Arizona
Medical Bacteriologist - Virologist	Kenneth F. Wertman, Ph. D., Professor and Head, Department of Microbiology and Medical Technology, University of Arizona
Planning Engineer & Acting Project Engineer	Gordon E. Davis, Head, Planning and Research Section, Water and Sewage Systems, City of Tucson
Sanitary Microbiologist	Robert A. Phillips, Ph. D., Associate Professor, Department of Civil Engineering, University of Arizona
Professional Investigator Research Associate	Peter P. Ludovici, Ph. D., Associate Professor, Department of Microbiology and Medical Technology, University of Arizona
Virologist	Robert J. Janssen, Ph. D., Assistant Professor, Department of Microbiology and Medical Technology, University of Arizona
Chemist	Everett J. Trueblood, Chief Chemist, Water and Sewage Systems, City of Tucson
Chemist	John F. Stafford, Project Chemist, Tucson Wastewater Reclamation Project, City of Tucson
Research Assistant	Alexandera Hodge, Department of Microbiology and Medical Technology, University of Arizona

Additional Staff

Project Position	
Microbiologist	Dr. Jaime Mendiola Visiting Researcher University of Guadalahara, Mexico
Chief Operator (Project Filter)	David R. Tanner, Diplomate Tucson Wastewater Reclamation Project
Research Assistant	Robert Wills Graduate Assistant - Civil Engineering University of Arizona
Assistant to Planning Engineer	Carl R. Nelson Asst. Planning Engineer Planning & Research Section Water & Sewage System City of Tucson
Technical Advisor	E. O. Dye, Superintendent Sewage System City of Tucson

1.05 ACKNOWLEDGEMENTS

Our Technical Planning Committee contributed significantly to our understanding of the project objectives. The three meetings of July 23, 1965, November 19, 1965, and June 24, 1966, held in the Water and Sewers Department conference room of the City of Tucson, devoted to the review of Project plans and progress, provided many and varied helpful suggestions.

Our thanks to those many persons in the Engineering, Production, and Distribution Divisions of the Water & Sewers Department, not listed above who have assisted with the project activities.

The Technical Planning Committee members are listed below:

TECHNICAL PLANNING COMMITTEE

1. EDMUND C. GARTHE, C. E., M. P. H., Director of Division of Environmental Health, Arizona State Department of Health, Chairman
2. QUENTIN M. MEES, M. S., P. E., Professor, Department of Civil Engineering, University of Arizona
3. KENNETH F. WERTMAN, Ph. D., Professor and Head, Department of Microbiology and Medical Technology, University of Arizona
4. FREDRICK J. BRADY, M. D., Director, Pima County Health Department
5. DONALD R. ANDERSON, Consulting Engineer, Manager, Engineering - Sciences, Inc., San Francisco Area Office
6. GERRY HAUER, Products Manager, Infilco, Inc., Tucson Arizona
7. WILLIAM MC CONNELL, Ph. D., University of Arizona, Head, Co-operative Fisheries Unit
8. PAUL BEERMANN, Director, Water & Sewers System, City of Tucson, Ex officio

CHAPTER 2

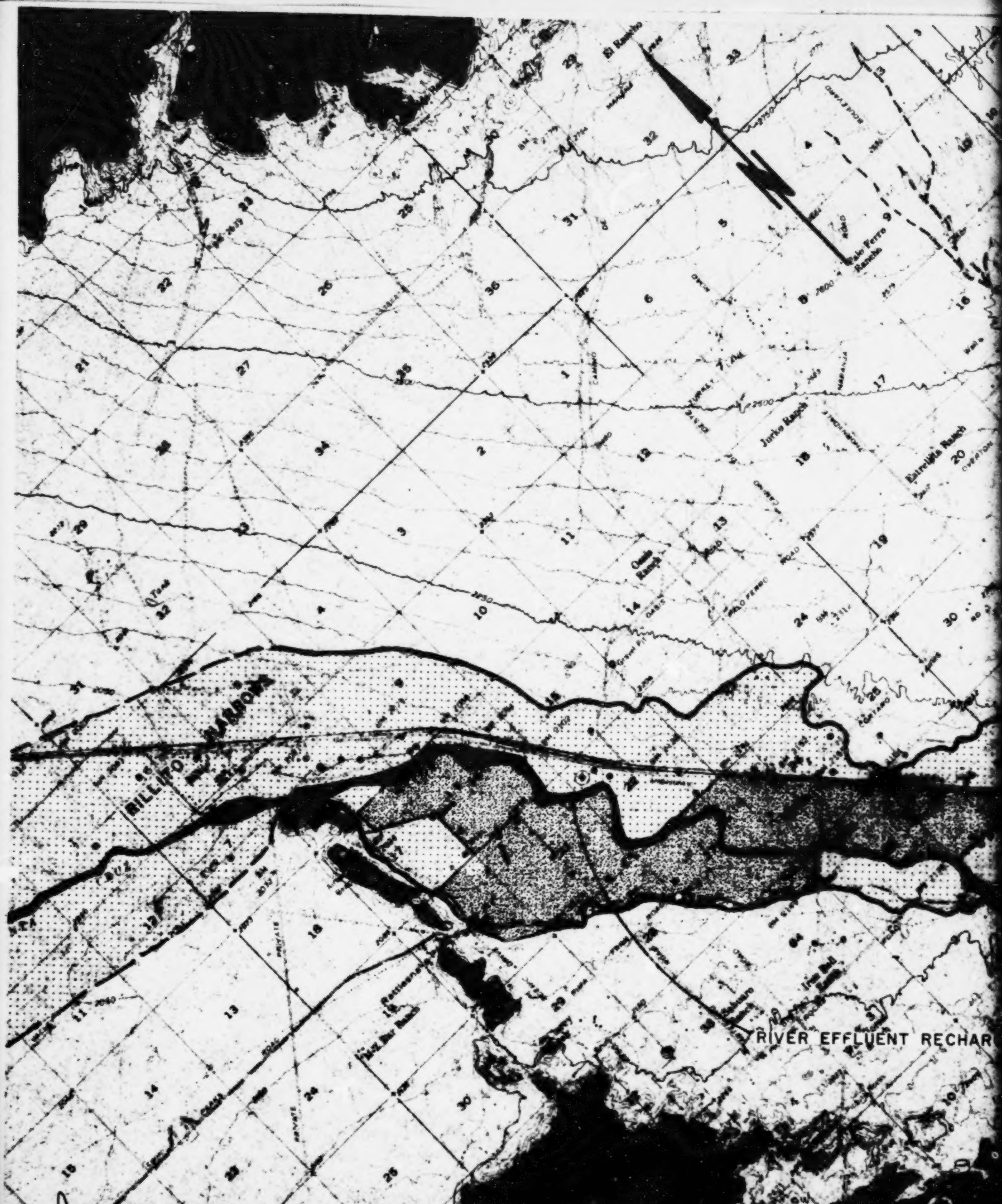
DESCRIPTION OF PROJECT AREA

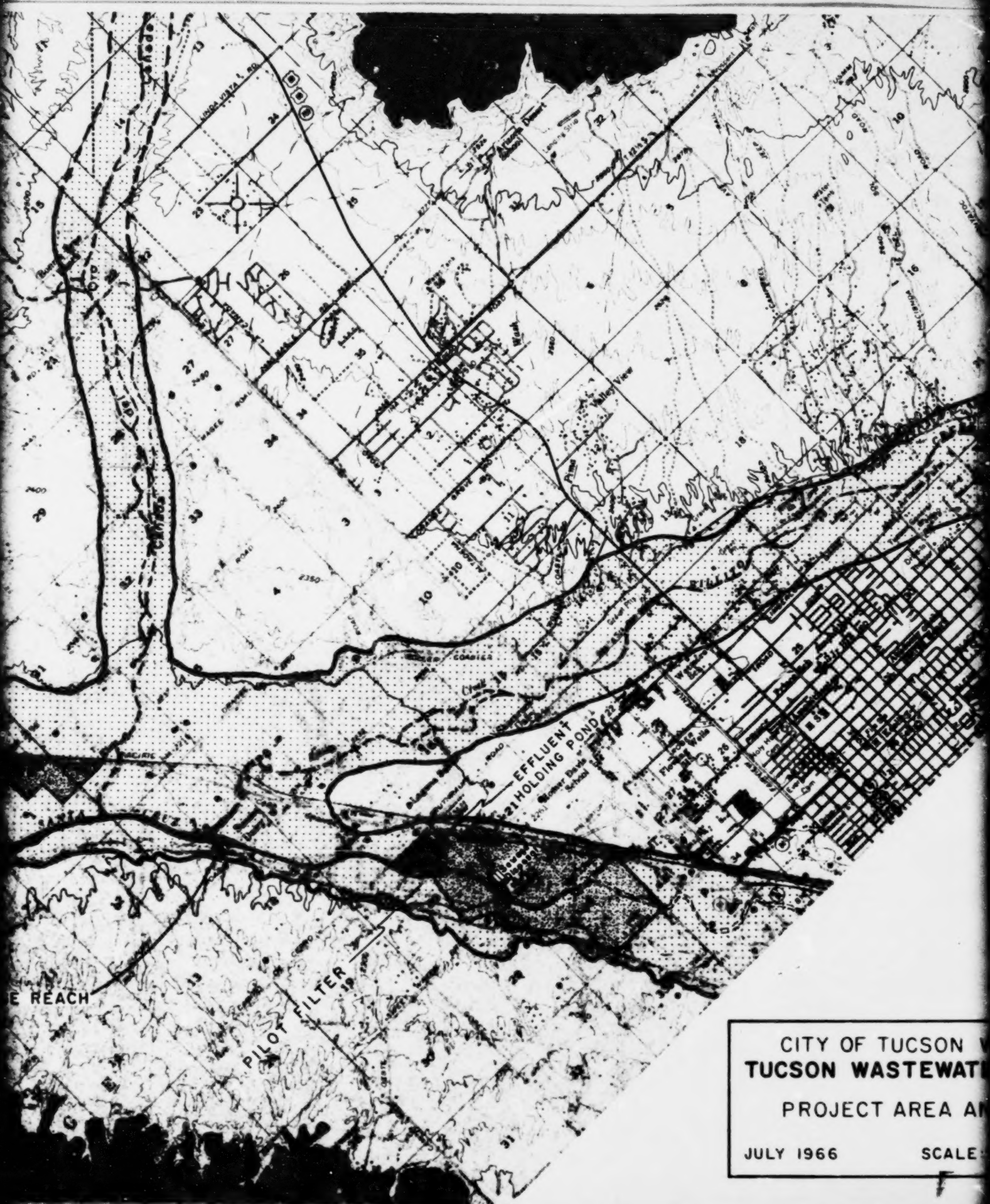
2.01 INTRODUCTION

The project area is divided into two sections for the purpose of description. The larger area encompasses the smaller and may be defined in the following manner:

> The larger area lies in the extreme northwest corner of the Tucson Basin, within the inner valley and bracketing the entrenched Santa Cruz River, an arid-type ephemoral stream. (Fig. 1). Rillito Creek and Canada del Oro, the principal tributaries, also ephemorals, merge with the Santa Cruz within the area. Here the river valley trends northwest at a slope of approximately 20'/mile between a broad valley incline sweeping east to the Catalina Mountains and 15-40 ft. bluffs bounding a westward slope into the Tucson Mountains.
>
> The smaller section defined as the pilot filter project area lies at an elevation of 2,240 feet within the larger section and some 3/4 of a mile northwest of the Tucson Wastewater Treatment Plant on City property on Santa Cruz River bottom land 7 miles northwest of downtown Tucson.

Weatherwise, this area enjoys abundant sunshine and a modest amount of rainfall which averaged only 10.47 inches annually between 1931-1965. The heaviest rains occur during two periods yearly, namely July through mid-September and December through March. The average annual temperature


El Rancho
Palo Ferro Rancho
Jurko Ranch
Estrellita Ranch
Ocala Ranch
OVERTON
PALO FERRO
ROAD
CAMINO
2500
BILLITO NARROWS
CRUZ
RIVER EFFLUENT RECHAR
A


EFFLUENT
HOLDING POND
PILOT FILTER
E REACH
SANTA CRUZ
RILLITO
Valley View
ROAD
CORTARO
PACIFIC

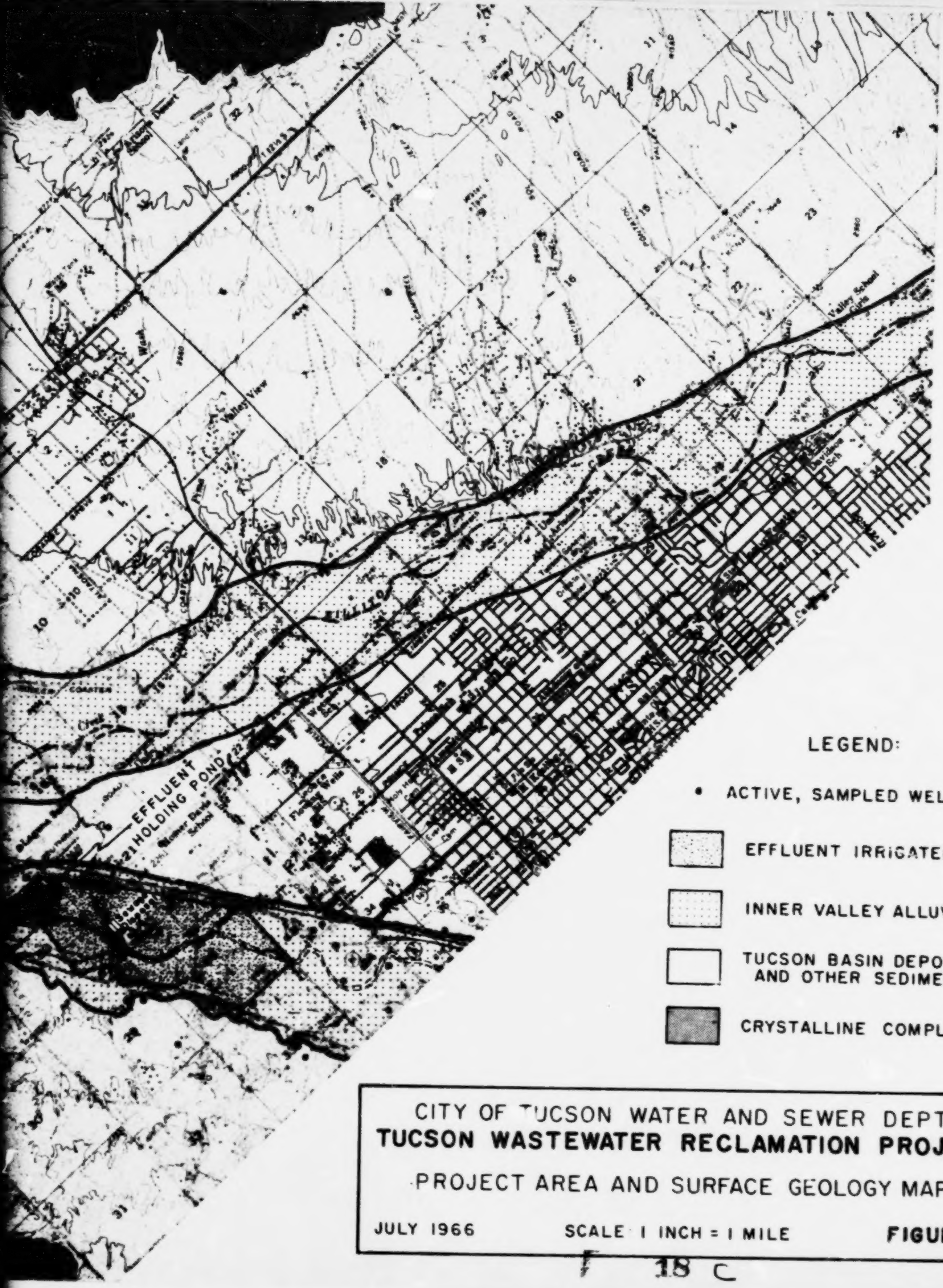
CITY OF TUCSON

TUCSON WASTEWAT

PROJECT AREA AN

JULY 1966

SCALE


EFFLUENT HOLDING POND
Valley View
TUCSON

LEGEND:

- ● ACTIVE, SAMPLED WELL
- ▨ EFFLUENT IRRIGATED AREA
- ▨ INNER VALLEY ALLUVIUM
- ☐ TUCSON BASIN DEPOSITS AND OTHER SEDIMENTS
- ▩ CRYSTALLINE COMPLEX

CITY OF TUCSON WATER AND SEWER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

PROJECT AREA AND SURFACE GEOLOGY MAP

JULY 1966 SCALE I INCH = I MILE **FIGURE I.**

is 67° F. with a diurnal variation of some 30° F., while summer temperatures of 105° are not uncommon.

2.02 GEOHYDROLOGY

The mountains to the west of the project area are volcanic while those to the east are predominantly metamorphic gneiss. Alluvial fan deposits of coarse sand and gravel make up the valley slopes extending from the base of the mountains to the inner valley. The Santa Cruz channel and flood plain are underlain by alluvial fills consisting of unconsolidated gravel, sand, and silt of 100 feet or more thickness.

Recognizing the importance of an understanding of the recent and sub-recent geology of the Santa Cruz River Basin in the project area to the detailed study of well water quality, a special geologic study was performed during the summer of 1965, immediately following project authorization.

The purpose of this study was to determine the geology pertinent to the recharge area of the Tucson Sewage Treatment Plant utilizing field work, the literature, air photos, and well logs. Future study will allow much detailed refinement and revision of this reconnaissance study. In the course of the study, a surface geological map (Fig. 1) showing terraces and general surface features, and as detailed a fence diagram (Plate 5, in pocket) as possible using existing well logs, were compiled for the effluent recharge area.

The stratigraphic terms used (from oldest to youngest) include: Pantano Group, Deformed Gravels, Tucson Basin Sediments, and Recent Alluvium. Probable equivalents of the above terms which appear in the literature include: Pantano Group equal to Red Mud Stones; Deformed Gravel equivalent to Pliocene Lake Beds equal to Rillito Beds equal to Tucson Aquifer;

Tucson Basin Sediments equivalent to Basin Fill Sediments; and Flood Plain Alluvium equal to Inner Valley Fill. There are discrepancies in the above equivalencies as used in the literature, particularly in the boundaries between the above divisions.

In the area of effluent recharge (Fig. 1), one is dealing primarily with three divisions of the subsurface--the Deformed Gravels, Tucson Basin Sediments, and the Recent Alluvium, the former being of much less importance as a local aquifer. All the wells used in construction of the fence diagram derive their water from the Tucson Basin Sediments.

The slope of ground water table in the project area approximates the surface stream's slope, 20 feet per mile toward the northwest. The water levels are at about 100 feet in the inner valley, increasing in depth to several hundred feet within two or three miles of the river. A record of water levels in selected wells within the Santa Cruz Valley from the City Farm to Rillito Narrows, about ten miles downstream, indicates the water level decline in the vicinity of the City Farm has been 50 feet in the period 1947 to 1964, and the water level records of nearby wells show continuing declines, probably resulting from the spreading influence of pumpage in the City area to the south and east. In contrast, wells downstream from Cortaro have generally declined less than ten feet in these years, and that in spite of an annual pumpage locally of about 20,000 acre feet for export to the agricultural area of Marana. In fact, about four square miles experienced a rise in water level of 4 to 5 feet from 1963 to 1965--a fact partly reflecting a decrease in the local pumpage for export to about 18,000 acre feet in this time, and partly due to increased effluent irrigation return water discharged into the river.

The most significant structural feature which would influence the sub-surface stratigraphy, and thus the hydrologic characteristics, would be the "Narrows," a sub-surface basin restriction at Rillito (See Fig.1). This restriction has a general northeast trending shallowing effect at the northwest end of the Tucson Basin and causes a sharp "bunching" of the water level contours. Based only on a hasty surficial examination, the restriction appears to be continuation of a local northeast trend of the Tucson Mountains (which preponderantly trend northwest).

The only other restricting or shaping factor would be the basin sides themselves (probably the true pediment slopes of the Tucson, Tortolita and Catalina Mountains) and possibly near vertical fault planes associated with the above mountain . Movement along various of these fault planes could conceivably block or open certain local aquifers without need of other explanations. Certain, scattered, appearances of some lithologies above expected levels in some wells (and their not appearing in adjacent wells) readily can be explained by this phenomenon.

The limited work on the surface geology achieved its maximum value in pointing to the need for further work of use in a hydrologic program (availability of impermeable materials for dike and retainer wells, accessible material suitable for filters, etc.).

The only feature noted for future reference was the one terrace represented by the inner valley alluvium and Tucson Basin Deposits contact which is readily discernable on air photos and, in a few instances, manifested on topographic maps as a bluff (Fig. 1). The origin of this particular terrace appears to be the Santa Cruz River's (and associated drainages) truncation of the presently developed bajadas of the surrounding mountains. This terrace is the probable equivalent of G. E. P. Smith's "University Terrace." Hints of minor terraces were in evidence in the field, but not mappable in the limited time available.

It would be desirable to prepare a workable geological map of the lower Tucson Basin, emphasizing lithologies and related textures, on a ten foot contour base map, thus showing minute changes significant to related problems of future studies. All of the above four stratigraphic divisions except the Pantano Group should be included on such a map.

CHAPTER 3

TUCSON WASTEWATER TREATMENT PLANT

3.01 INTRODUCTION

Crops have been irrigated by Tucson's sewage for 65 years or throughout the system's history. Raw sewage was utilized for irrigation of grain crops from 1900 to 1928, when the first primary treatment plant was constructed. Thereafter, increasing amounts of treated effluent have been used for irrigation of various crops, principally on the City Farm, until 1965 when a total of approximately 1,700 acres were irrigated.

The present Tucson Sewage Treatment facilities will accommodate 24 MGD of sewage flow and consist of a 12 MGD standard activated sludge plant constructed in 1950 operating in parallel with a 12 MGD high-rate trickling filter plant completed in 1960, both fed from a common outfall source. At the present, a 12 MGD addition to the activated sludge plant is underway.

3.02 QUANTITY OF WASTEWATER

The two Tucson Sewage Treatment Plants produced six billion nine hundred million (6,900,000,000) gallons or 21,300 acre feet of effluent through primary and secondary treatment during 1965. Shortly after 1970, plant production is expected to be about 30,000 acre feet or 10,000,000,000 gallons. Effluent production was very uniform during 1965, ranging only from 17 million gallons a day (MGD) during winter to 22 MGD during summer.

Since the wastewater of Tucson's system is derived largely from domestic sources, a large hourly variation results each day at the plant with a low flow at about 6:00 a.m. and a peak flow at about 1:00 p.m. Infiltration of storm waters is not a significant factor of variation in flow of wastes to the plant because the storm sewers are a separate system.

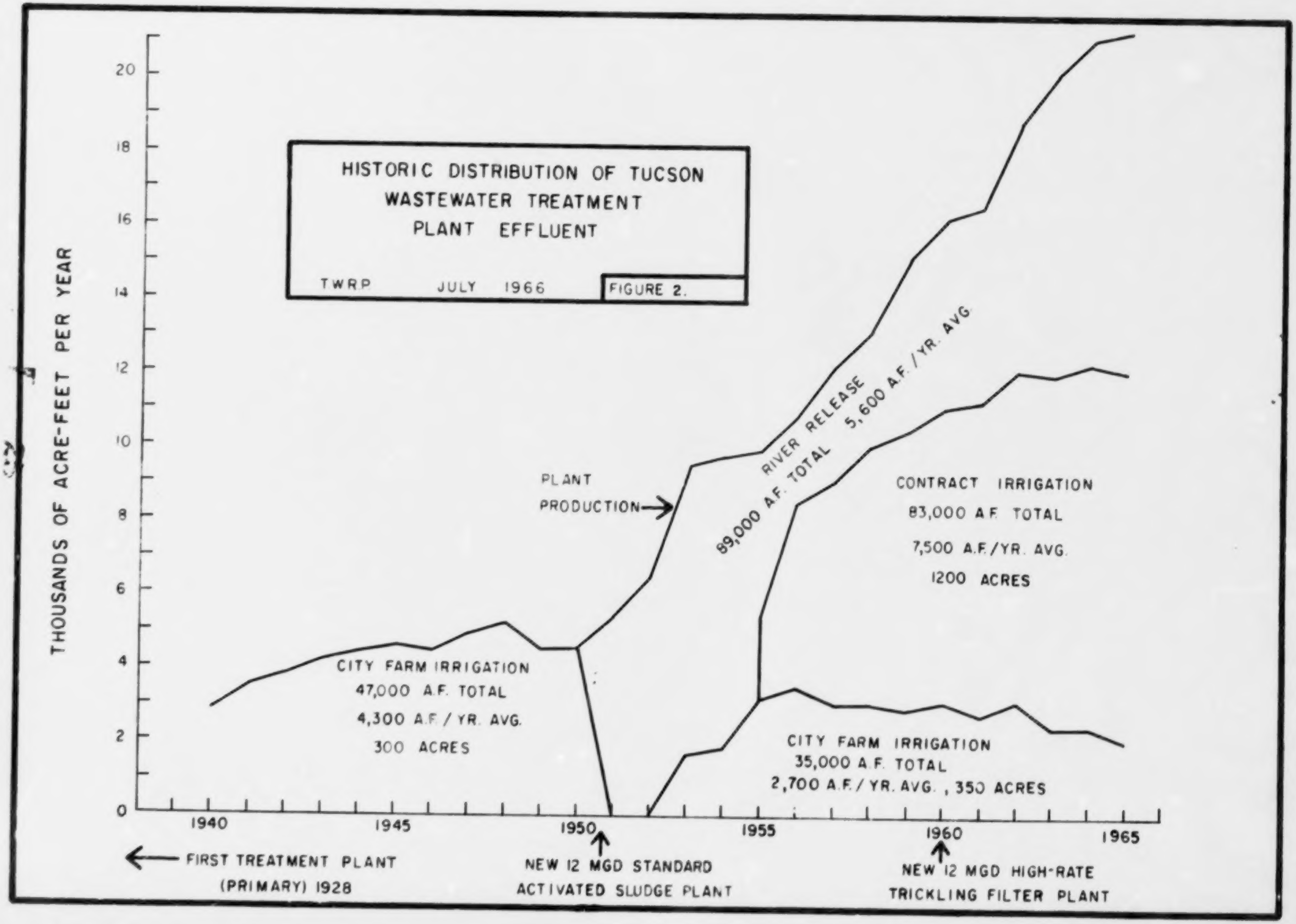
Total annual effluent production for the period 1940 to 1965 may be referred to in Table 1 and Figure 2. A schematic distribution of plant effluent for the same period is presented in Figure 3. The secondary treatment plant constructed in 1951 has produced an average of 13,800 acre feet per year to 1965 and an estimated annual average of 5,600 acre feet has been released into the Santa Cruz River in this period.

3.03 QUALITY OF WASTEWATER

Tucson's influent wastewater can be classified as fresh, moderately weak, typical domestic sewage. The 1965 annual report lists raw sewage averages of 255 ppm suspended solids and 222 ppm 5-day biochemical oxygen demand (BOD). The treatments employed are effective, as the final effluent averages are 34 ppm suspended solids and 48 ppm BOD, or average removals of 87 and 78 percent respectively. The activated sludge plant is somewhat more effective than the high-rate trickling filter plant, as can be seen in the comparison of effluents reproduced in Table 2.

Tucson's municipal water supply is drawn exclusively from deep wells spread across the Tucson Basin, and some variation in chemical quality of well water is experienced. However, comparison of typical well water quality with raw sewage confirms the range of 100 to 300 ppm increases in total dissolved solids with a single cycle of domestic use.

It should be noted that, on the average, Tucson effluent contains 26 ppm total nitrogen and 30 ppm phosphate, both constituents of great



HISTORIC DISTRIBUTION OF TUCSON WASTEWATER TREATMENT PLANT EFFLUENT

TWRP JULY 1966

FIGURE 2.

TABLE 1

HISTORIC TUCSON WASTEWATER TREATMENT PLANT EFFLUENT DISTRIBUTION 1940-65
(Acre-Feet)

Year	TWTP Effluent	City Farm Irrigation	TWTP Grounds Irrigation	Contract Irrigation (Est.)	River Release (Est.)
1940	2,820	2,820			Estimated Maximum 5% Of Annual Production
1941	3,450	3,450			
1942	3,770	3,770			
1943	4,220	4,220			
1944	4,460	4,460			
1945	4,620	4,620			
1946	4,410	4,410			
1947	4,950	4,950			
1948	5,190	5,190			
1949	4,500	4,500			
1950	4,570	4,570			
1951	5,320	0			5,320
1952	6,530	0	10		6,520
1953	9,530	* 1,680	20		7,830
1954	9,720	1,850	20		7,850
1955	9,950	3,230	30	** 2,170	4,520
1956	10,870	3,550	20	5,000	2,300
1957	12,290	3,040	50	6,000	3,200
1958	13,280	3,070	90	7,000	3,120
1959	15,170	2,940	70	7,500	4,660
1960	16,280	3,100	60	8,000	5,120
1961	16,650	2,740	70	8,500	5,340
1962	18,910	3,120	80	9,000	6,710
1963	20,190	2,310	130	9,500	8,250
1964	21,150	2,320	110	10,000	8,720
1965	21,300	2,010	130	10,000	9,160

* 1953 Lease of City Farm.

** 1955 Contract Sale of Surplus Effluent.

TABLE 2

ANALYSES
TUCSON WASTEWATER TREATMENT PLANT

	Influent	Activated Sludge Effluent	Trickling Filter Effluent
Date	20 IV 66	20 IV 66	20 IV 66
Hour	0945	1055	1050
Flow MGD	21	9.5	9.5
°C	24	23	23
p^H	8.1	7.8	7.8
TSS	1030	681	665
FS	508	462	445
VS	522	219	220
SS	296	10	27
TS	1326	691	692
Ca	123	67	34
Mg	29	37	23
NH_4	30	20	18
Na (diff)	152	90	140
Cl	236	83	89
HCO_3	329	325	298
SO_4	224	180	158
CO_3	0	0	0
Org.-N	10.6	3.8	5.0
D.O.	0.6	6.4	3.3
B.O.D.	268	21	39

NOTE: All results in p.p.m.

SCHEMATIC DISTRIBUTION OF TUCSON WASTEWATER TREATMENT PLANT EFFLUENT, 1940 – 1965

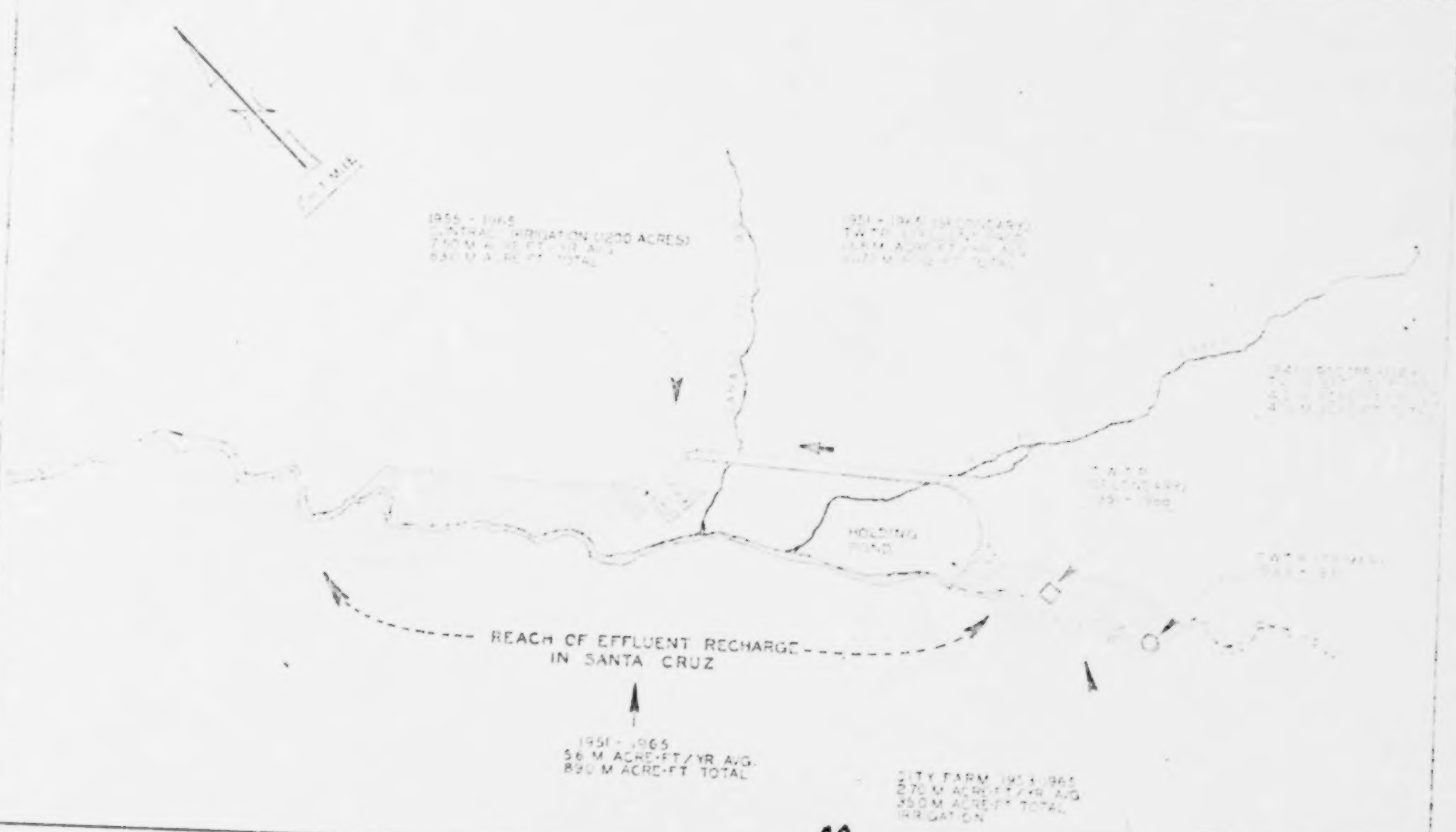

1 MILE
1955 - 1965
CONTRACT IRRIGATION (1200 ACRES)
M ACRE-FT TOTAL
1951 - 1965 (SECONDARY)
T.W.T.P.
M ACRE-FT TOTAL
HOLDING POND
T.W.T.P.
(SECONDARY)
1951 - 1965
T.W.T.P. (PRIMARY)
REACH OF EFFLUENT RECHARGE IN SANTA CRUZ
1951 - 1965
56 M ACRE-FT/YR AVG.
890 M ACRE-FT TOTAL
CITY FARM 1951-1965
270 M ACRE-FT/YR AVG
350 M ACRE-FT TOTAL
IRRIGATION

FIGURE 3

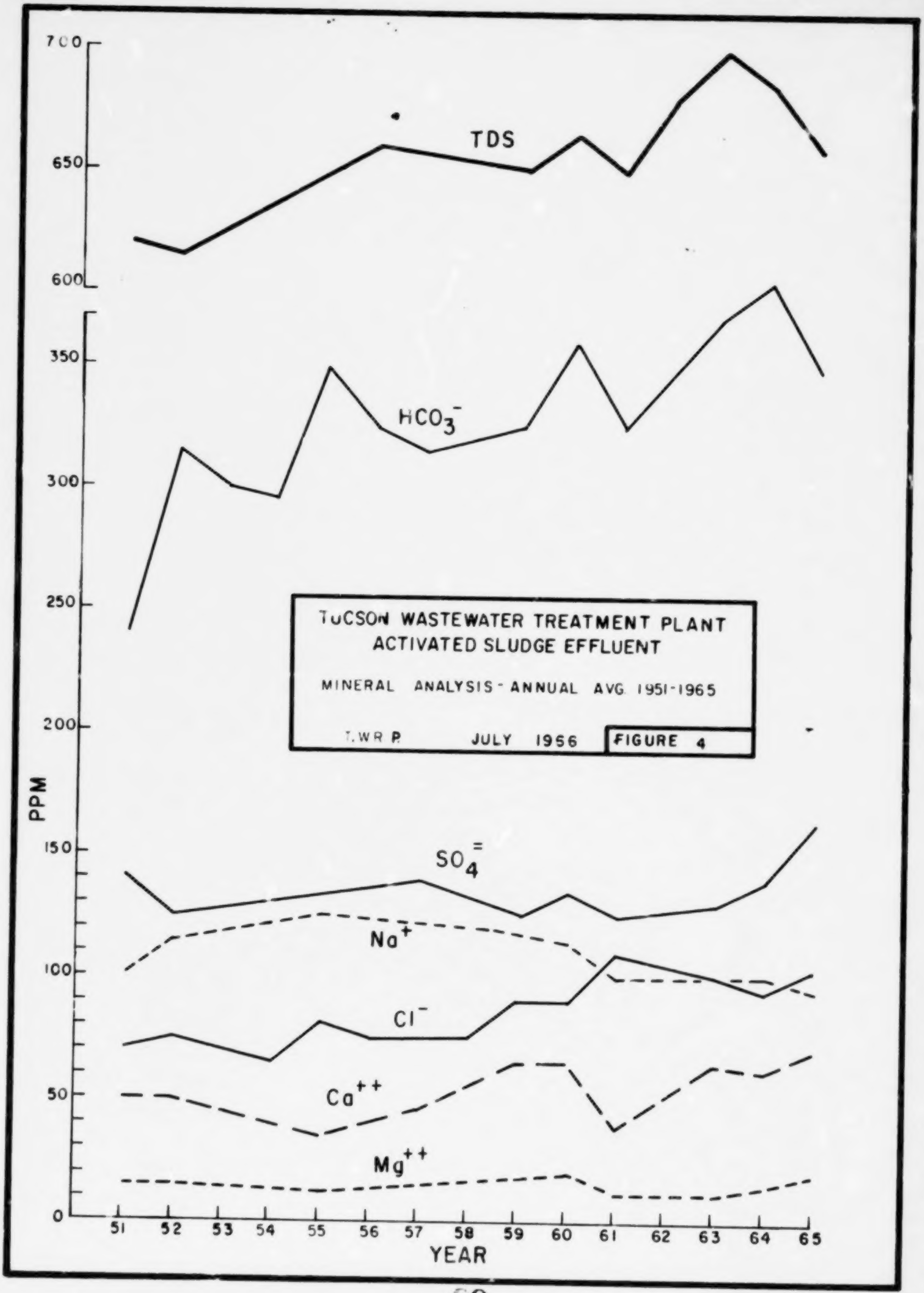
value as fertilizer for agricultural uses.

In order to more firmly illustrate the character of the Tucson Wastewater Treatment Plant, data were gathered from the official historical records of the activated sewage effluent plant and plotted on a 1951-1965 scale. See Figures 4, 5, and 6.

Figure 4 contains the extant mineral analyses performed on the TWTP effluent between 1951 and 1965 on an annual average basis. A significant increase in total dissolved solids, bicarbonate and chloride, probably can be attributed to expansion of the City well field, during this period, into areas of greater ground water mineralization--i.e. the major well field development upstream on the Santa Cruz River which began in 1955.

Figure 5 is a representation of the important organic constitutents found in secondary effluent over the period 1951-1965. The quality variation during the period 1951-52 has been documented to be attributable to a deliberate change in plant operation. By contrast, the period 1960-61 resulted from a marked variation in plant performance brought about by construction of a second 12 MGD plant. Figure 6 shows the range and variation of biochemical oxygen demand, dissolved oxygen and $_pH$ over the same 15 year period.

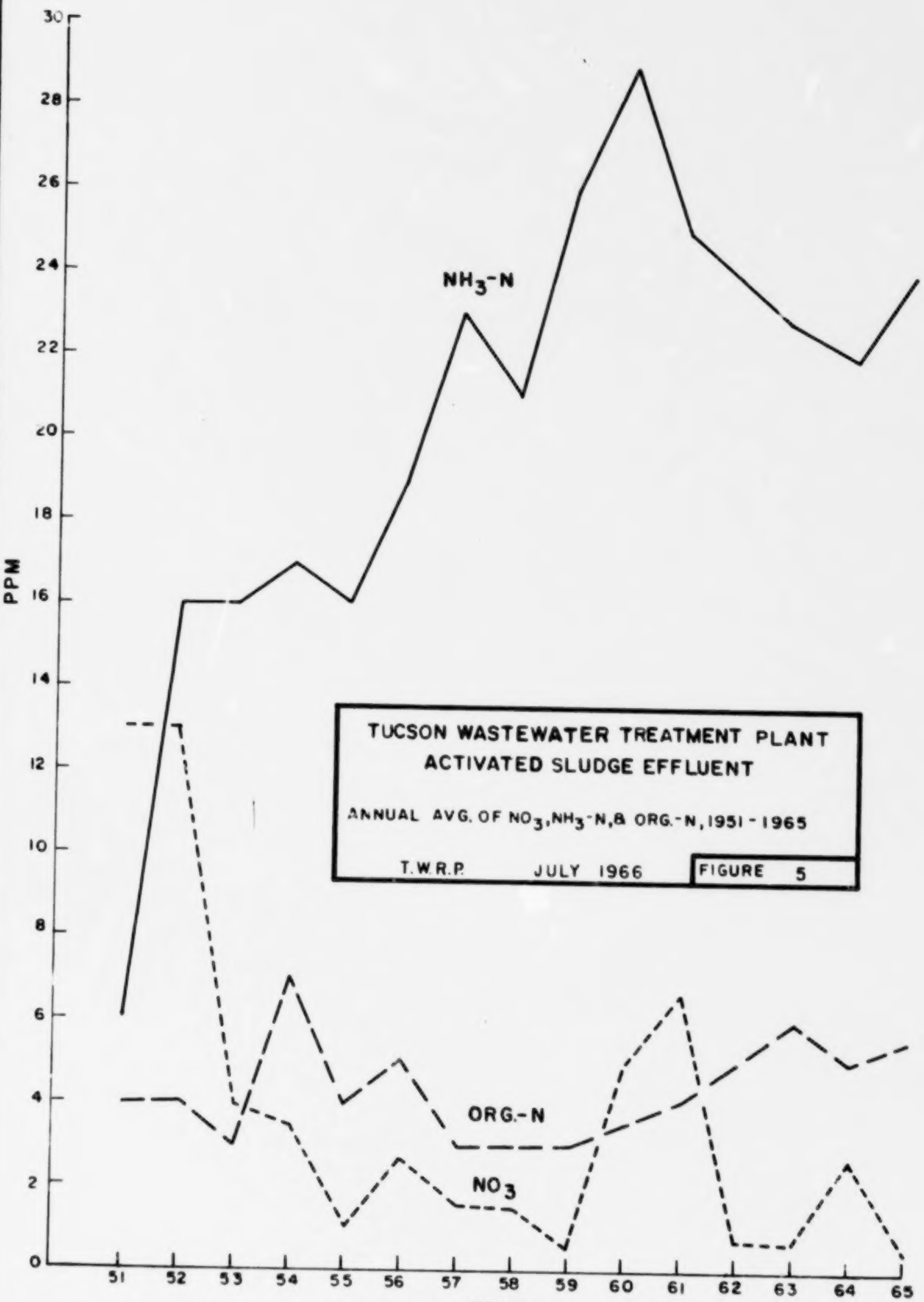
To further characterize and evaluate the activated sludge effluent, Figure 7, the 1965-66 monthly range and variation of $_pH$, B.O.D., D.O., and Temperature, is included. The monthly variations of B.O.D. and D.O. indicate the physical effect of average temperature variation. The D.O. concentration varies inversely and the B.O.D. directly with the average monthly temperature.



TUCSON WASTEWATER TREATMENT PLANT
ACTIVATED SLUDGE EFFLUENT

MINERAL ANALYSIS - ANNUAL AVG. 1951-1965

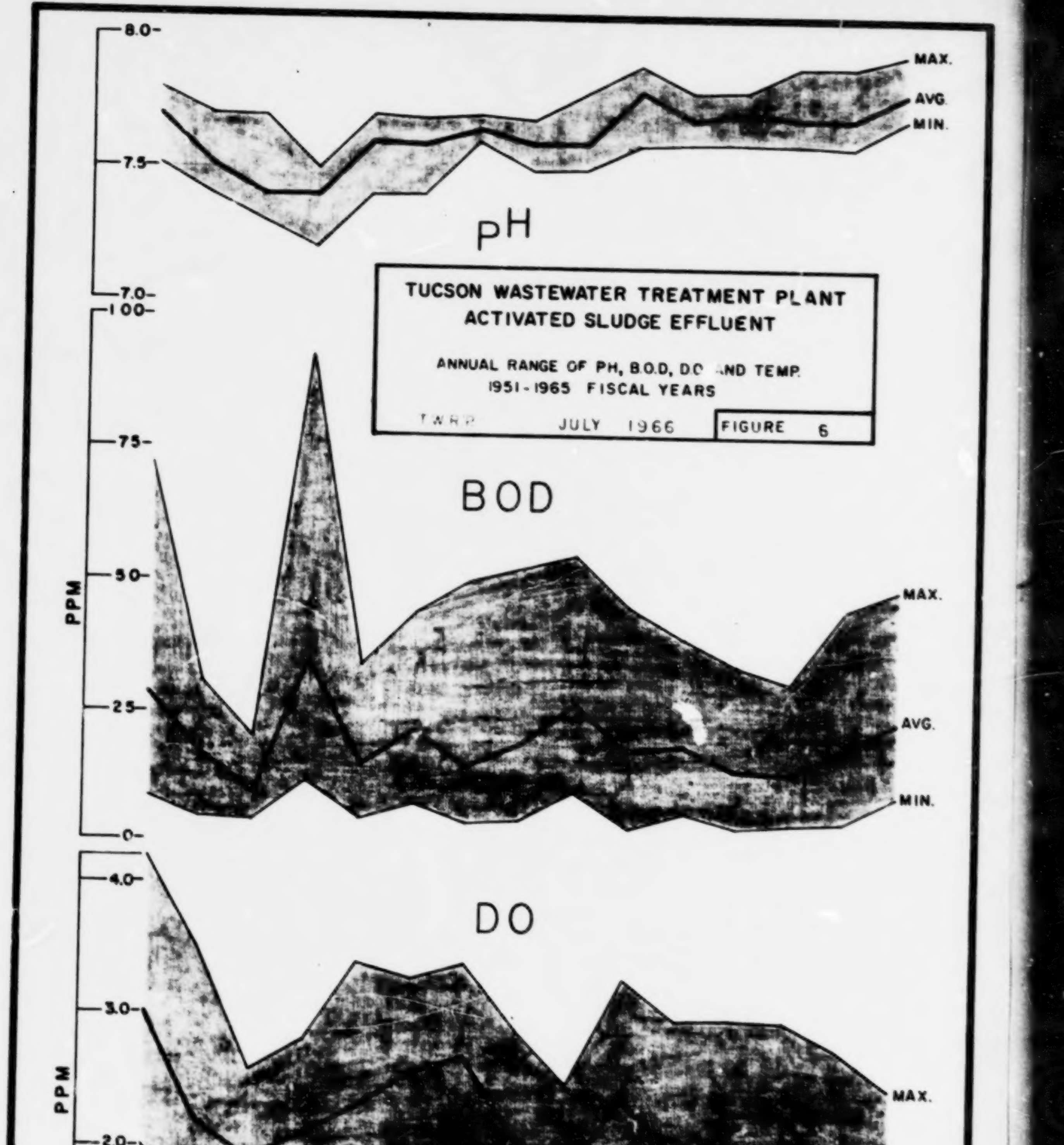
T.W.R.P. JULY 1956 FIGURE 4



TUCSON WASTEWATER TREATMENT PLANT
ACTIVATED SLUDGE EFFLUENT

ANNUAL AVG. OF NO$_3$, NH$_3$-N, & ORG.-N, 1951 - 1965

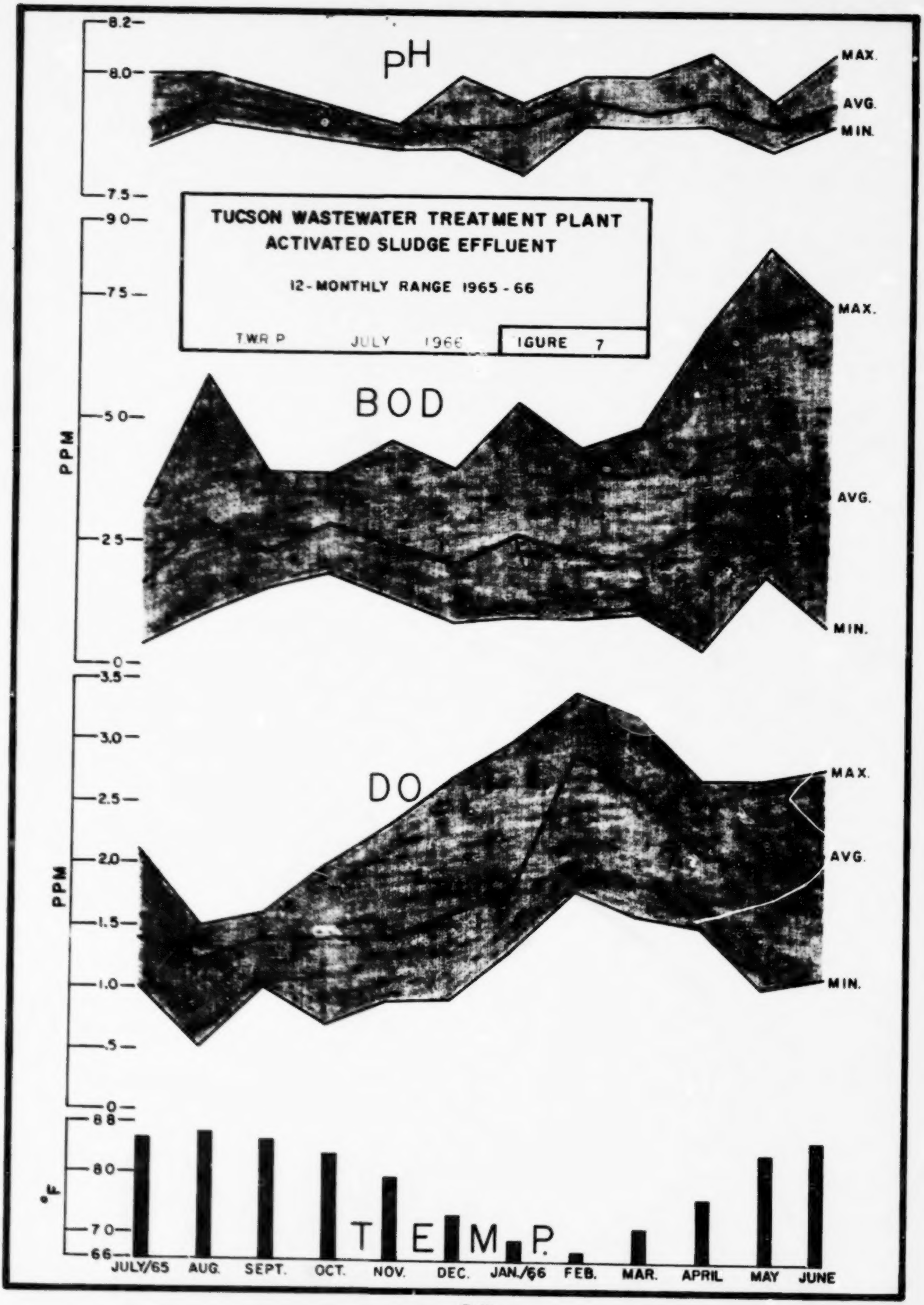
T.W.R.P. JULY 1966 FIGURE 5



TUCSON WASTEWATER TREATMENT PLANT
ACTIVATED SLUDGE EFFLUENT

ANNUAL RANGE OF PH, B.O.D, DO AND TEMP.
1951-1965 FISCAL YEARS

TWRP JULY 1966 FIGURE 6



TUCSON WASTEWATER TREATMENT PLANT
ACTIVATED SLUDGE EFFLUENT

12-MONTHLY RANGE 1965 - 66

T.W.R.P. JULY 1966 FIGURE 7

CHAPTER 4

EFFLUENT RECHARGE AREA

4.01 INTRODUCTION

This study phase is directed toward determining the chemical, biological, and virological characteristics of water obtained from a representative number of wells located within the area of effluent recharge influence approximately two miles wide and extending fourteen miles along the Santa Cruz River downstream from the existing Sewerage Treatment Plant. The index map (Fig. 1) of the Santa Crux River Basin downstream from the Sewage Treatment Plant (NW) shows precisely that area under consideration by this project. The solid blue dots indicate the sampled wells on which both current and/or historic data is available relative to chemical as well as physical characteristics. In order to quickly and permanently locate each well within the study area the "in-use" system of the "Bureau of Land Management" subdivision method was utilized. This system of numbering affords immediate recognition of any well location by using a series of numerals and letters signifying the 1/4 1/4 1/4 Section, the Township, the Range, and the quadrant. For example, a well with the designation of (D-12-12)21 baa is located in South Eastern Arizona in Township 12 South, Range 12 East, in the NE 1/4 NE 1/4 NW 1/4 Section 21.

4.02 DATA AQUISITION

Base map preparation required collection, tabulation, and assimilation of available data on approximately 200 irrigation, industrial, and domestic water wells constructed within the 30 square mile study area, and all information confirmed in the field, prior to the entry on the project base maps. Particular attention was given to chemical analyses of well

waters previously collected from the area over a period of years, some dating back to 1920. To assist in the data assimilation, well tabulations and chemical analyses compilation forms were developed and utilized (TWRP Forms 5 & 6).
The geological frame work of the study area was developed utilizing well inventory data, including drillers formation logs, as well as other available information, all supplemented by field inspection.

In order to provide for an adequate evaluation of the project area wells, an intensive program of chemical, bacteriological and virological sampling was undertaken. One hundred and five (105) wells, approximately 50% of those functioning, were sampled at regular intervals and the resultant data was accummulated on a special tabulation sheet for each well.

Further criteria were needed to aid in the final selection of project wells to be continually monitored. It was decided to critically catagorize the wells individually on the basis of twelve items enummerated on a specially prepared evaulation sheet. At the same time a strict physical study of the individual wells was indicated to further qualify their character expecially as to any relationship which might obtain with the Chemical Analyses, Bacteriology, and Virology.

Working map sets of well construction, historical chemical water quality, current chemical water quality, and bacteriological quality ave been compiled from previously available and recently acquired data in preparation of selection of project wells to be sampled in asystematic program. Toward that end, interpretation and comparative studies of current and previous chemical analyses, and bacteriological analyses of well waters are underway with due consideration being given age and depth of well, proximity to effluent recharge area, and other physical site conditions which might contribute to bacteriological quality of well water.

4.03 CHEMICAL QUALITY OF WELL WATERS

All physical and chemical determinations on the subject samples comply with methods set forth in "Standard Methods for the Examination of Water and Waste Water," 11th and 12th editions, with the following exceptions:

1. Apparent ABS by methylene blue method set forth in "Determination of Anionic Surface - Active Materials in Sewage, Sewage Effluents, and River Waters." J. Longwell & W. D. Maniece, Analyst 1955, vol. 80, page 16f.
2. Fluoride was determined by the Alizarin Complexan - Lauthanum nitrate method of Belcher & West, Talanta 1961, vol. 8, page 853.

The analytical chemical approach to an understanding of the degree of effluent infiltration and consequent dispersion in the ground water has been centered on the nitrogen spectrum (Org-N, NH_3-N, NO_2-N and NO_3), phosphates, (PO_4), synthetic detergents and chlorides; however, complete mineral analyses were conducted on all wells sampled during the study for comparison with similar analyses previously available. Study of the variations of these indicators, which tend to point out by their presence or absence the degree to which the ground water quality has been altered, was completed. However, except in the broad sense, in limited zones of the study area, it is too early to establish exact relationships. It can be stated at this time, however, that nitrate (NO_3) concentrations range from 0 ppm to well in excess of 100 ppm in well waters within the project area and that ammonia-nitrogen (NH_3-N) is not uncommon up to 20 ppm.

All water samples were collected in widemouth polyethylene gallon bottles. The wells were sampled directly where possible or through pressure tanks when not possible. A three minute flushing period was utilized to clear lines and to approximate a homogenous sample. Temperature was immediately recorded. Upon deposit of samples at the laboratory they were stored at 40° F immediately after first being analysed for pH, ORP, EC, HCO_3 alkalinity, and chlorides. The nitrogenous components were determined within the first 24 hour period and the general mineralogy was finished within the week.

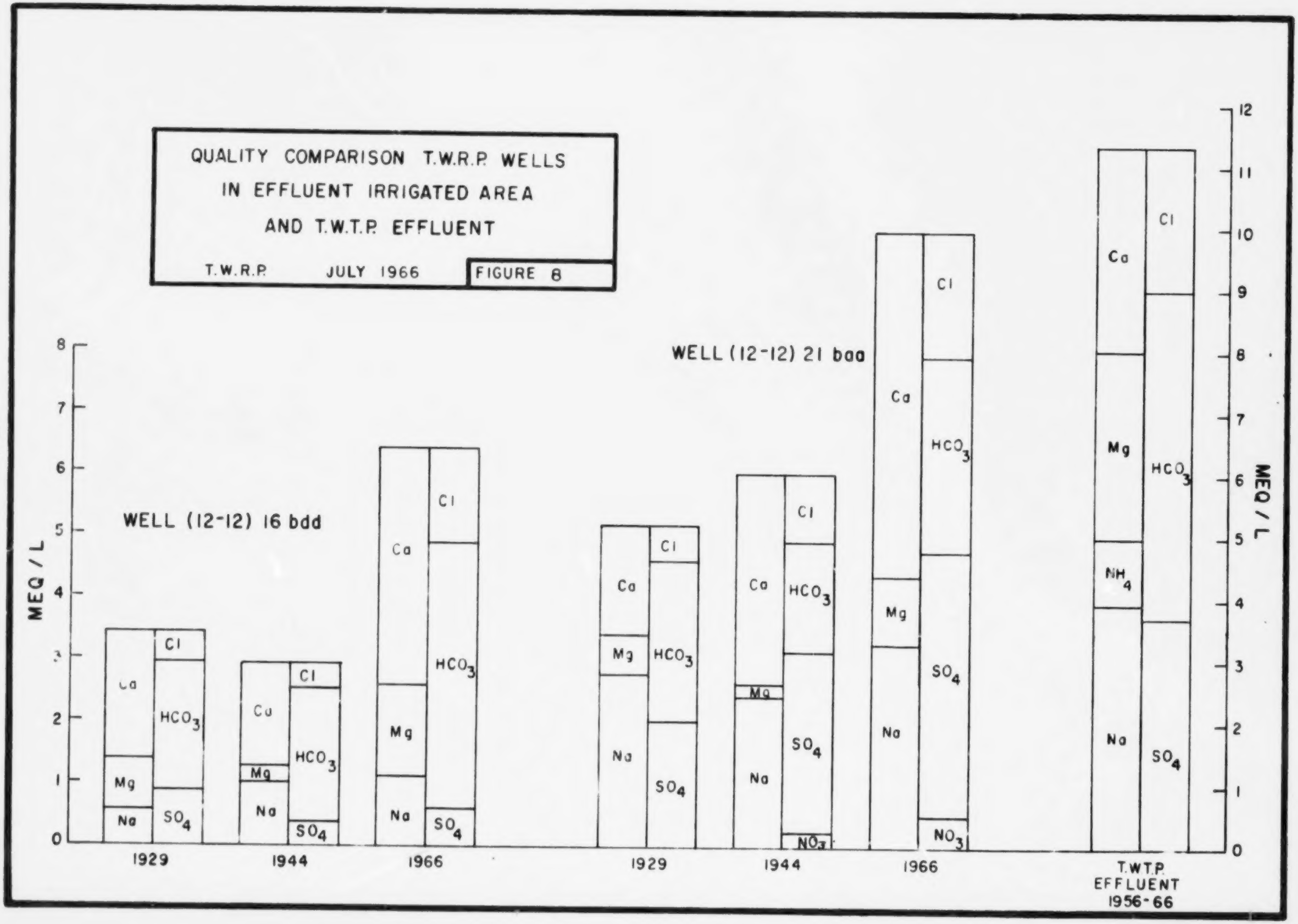
In order to properly evaluate the chemical results within the area, certain parameters were established for the purpose of plotting a profile of the wells under consideration so that a later eye-ball examination could be used to suggest some probable conclusions.

For the foregoing purpose base-maps of the investigation area were oriented as to geography and connected with each other on a flat wall surface and unique milliequivalents per liter (meq/l) kite scales in miniture were chosen to represent each individual well as to Na, Ca, Mg cations, sinistra, and Cl, HCO_3, SO_4 anions, dextra, with NO_3, as the kite's tail. Water levels and well depths were plotted thermometrically and A.B.S. & F. ions indicated in parts per million. A reference indicator of limiting elemental concertrations in parts per million, was prepared to epitomize the U. S. Public Health Service standards where applicable (TDS, Cl, SO_4, NO_3) and plotted as a meq/l "kite" and appended as an index to the base maps for reference scrutiny.

4.04 EFFECT OF EFFLUENT IRRIGATION AND RECHARGE

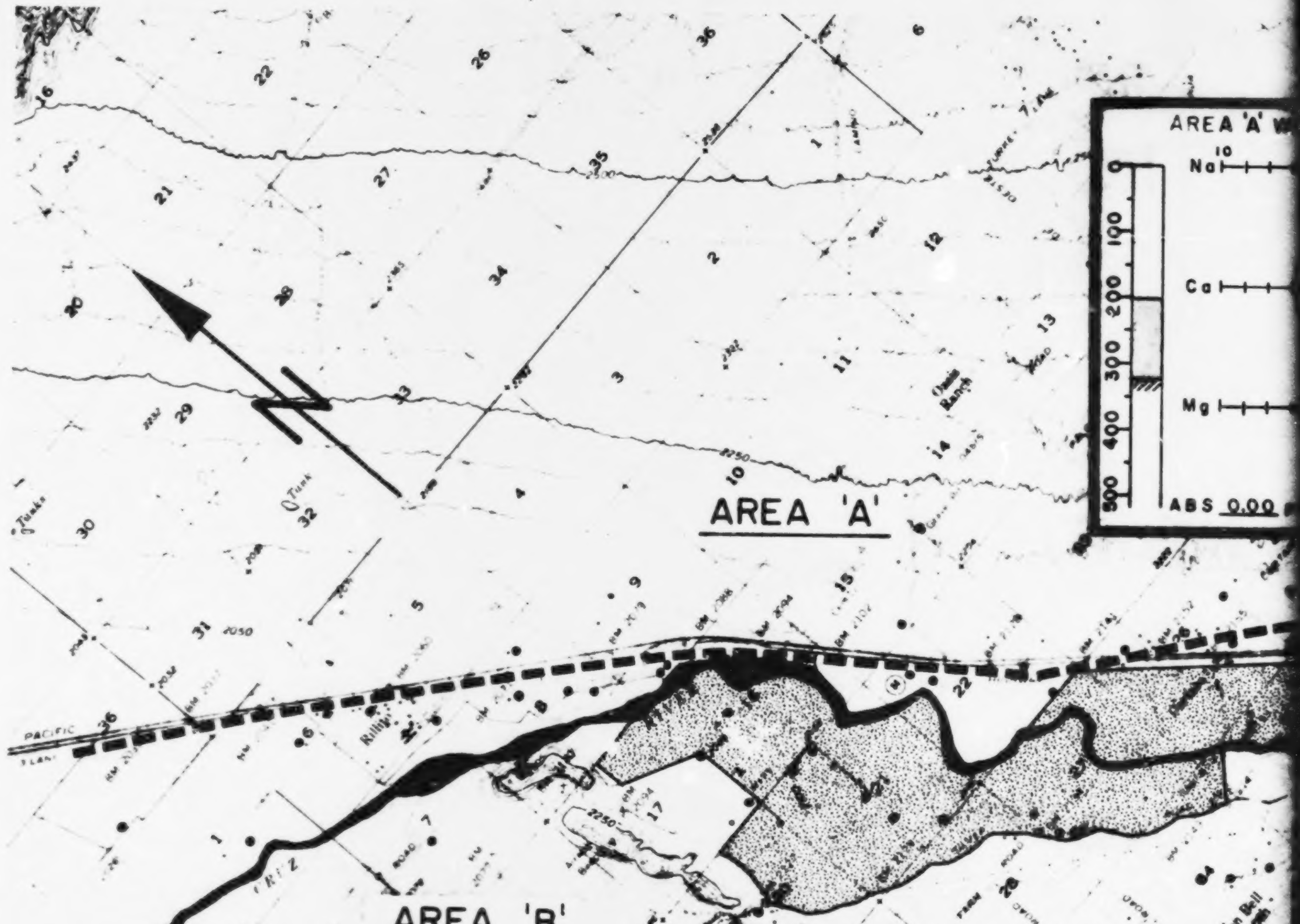
Reference to the schematic distribution of the Tucson Wastewater Reclamation Project effluent (Fig. 3) will aid in understanding of the discussion dealing with changes of chemical quality of ground waters in the irrigated area. As previously stated, an average of 7,500 acre feet per year of secondary effluent has been transported and applied to the contract irrigation area for the period 1955-65. Prior to 1955, and as early as 1920, this area was irrigated with pumped ground water locally produced and a substantial number of well water chemical quality records were available to the authors. Figure 8 is a representation of two such wells within this effluent irrigated area as to their historic chemical quality in comparison to the average quality of effluent applied over the last ten years. Depreciation of the ground water chemical quality is dramatically demonstrated.

Chemical quality comparisons throughout the project area have been represented on Figure 9, making use of the meq./l "kite" graphic plot. The legend of Figure 9 clearly explains the comparison of area water quality to a 500 ppm phantom. Area "A" water is of very good quality because it is derived from local mountain runoff and lies outside the main channel of the Santa Cruz River. Prior to the effluent irrigation period Area "B" water represented a transitional quality, influenced by both the pure mountain runoff and the higher concentration Santa Cruz Valley waters, and averaged generally between 300 and 500 ppm T.D.S. In 1965-66 the ground water quality was found to have depreciated by 150 to 300 ppm T.D.S. to a range generally from 500 to 800 ppm T.D.S. Area "C" water quality of 1965-66, while relatively high in T.D.S. generally has not changed appreciably during the last 30 years. Mention should be made however that this water may be characterized as "Sodium-Sulphate" type when compared to "Calcium-Carbonate" type of Areas "A" and "B". Nitrate and Alkyl Benzene Sulfonate (A.B.S.) were found in the waters within the project area mainly within the effluent irrigated area and near the main channel of the Santa Cruz. Figures 10 and 11 were included to indicate specifically which areas were most heavily infiltrated by these contamination indicators. The concentrations of these constituents show

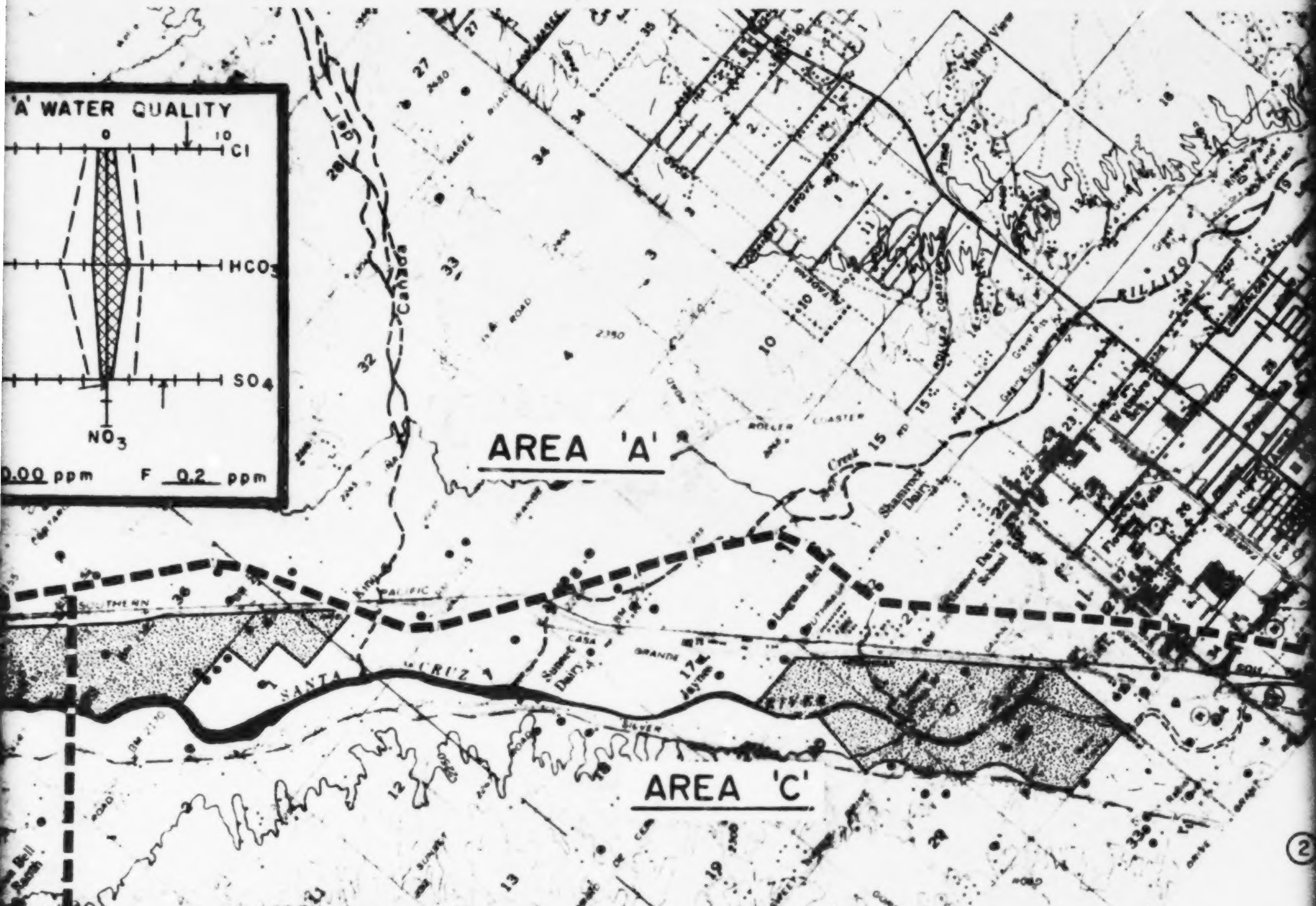


QUALITY COMPARISON T.W.R.P. WELLS
IN EFFLUENT IRRIGATED AREA
AND T.W.T.P. EFFLUENT

T.W.R.P. JULY 1966 FIGURE 8


AREA 'A'
AREA 'B'
AREA 'A' W
Na
Ca
Mg
ABS 0.00
AREA 'B' WATER QUALITY
Na
Cl
Ca
HCO3
Mg
SO4
NO3
ABS 0.05 ppm
F 0.2 ppm
0
100
200
300
400
500
10
SANTA CRUZ
PACIFIC
Rillito
Rattlesnake
M-Z Bar Ranch
Iron Bell Ranch
ROAD
Tank
2050
2250

A


'A' WATER QUALITY
0
10
Cl
HCO3
SO4
NO3
0.00 ppm
F 0.2 ppm
AREA 'A'
AREA 'C'
SANTA CRUZ RIVER
SOUTHERN PACIFIC
CASA GRANDE
Cañada
RILLITO
Shamrock Dairy
Sunset Dairy
Roller Coaster
AREA 'C' WATER QUALITY
10
0
10
Na
Cl
Ca
HCO3
Mg
SO4
NO3
0
100
200
300
400
500
ABS 0.00 ppm
F 0.3 ppm

②

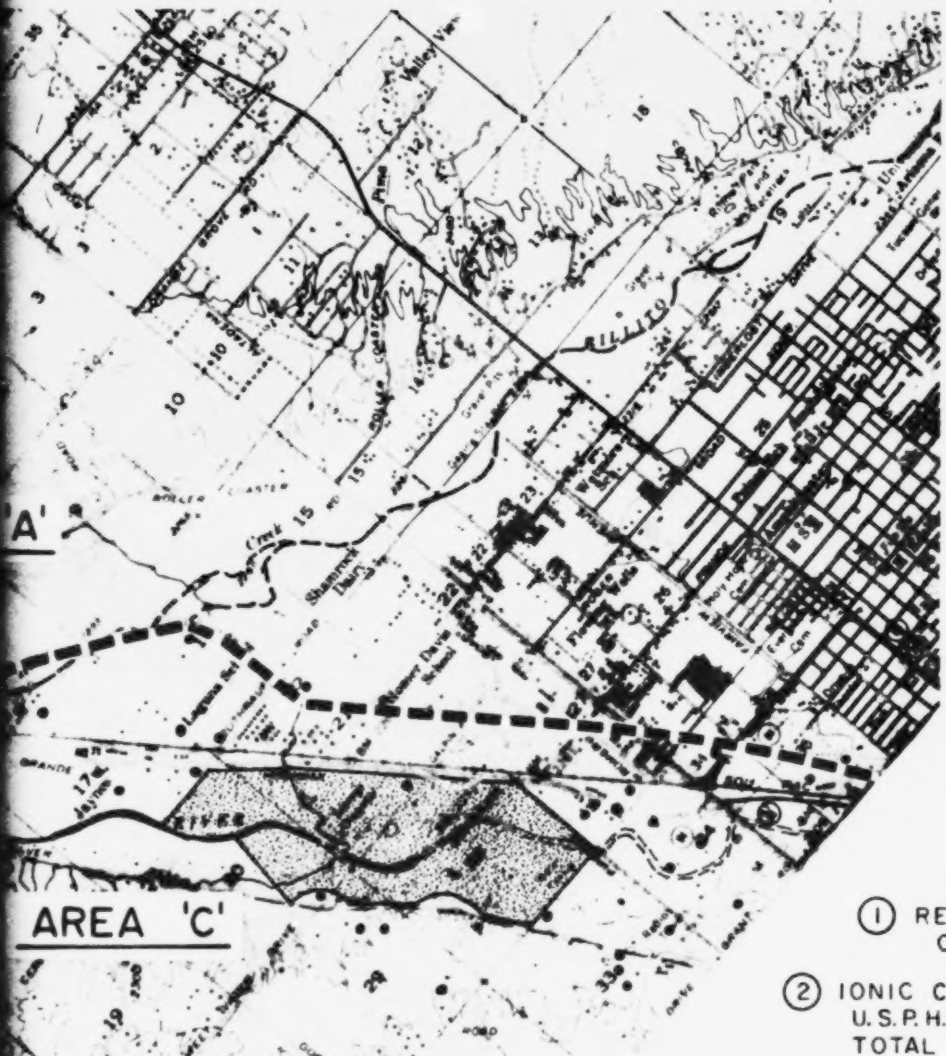
③ INDICA
FOR

④ REPRESENT
WELL SH

CITY OF T
TUCSON WAS

JULY 1966

B


'A'
AREA 'C'
RILLITO
RIVER

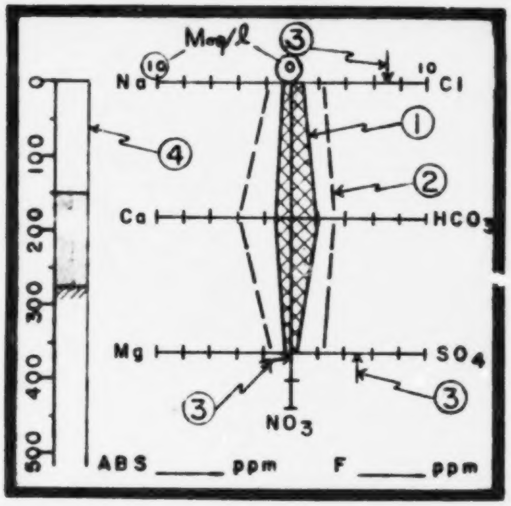
LEGEND:

● ACTIVE, SAMPLED WELL

▨ EFFLUENT IRRIGATED AREA

▬ ▬ ▬ WATER QUALITY AREA BOUNDARY

FOR EACH WATER QUALITY AREA:


Meq/ℓ
③
10
0
10
Na
Cl
①
④
②
Ca
HCO3
Mg
SO4
③
③
NO3
0
100
200
300
400
500
ABS _____ ppm
F _____ ppm

① REPRESENTATIVE DISTRIBUTION OF IONIC CONCENTRATION IN WELL WATERS (Meq/ℓ)

② IONIC CONCENTRATION DISTRIBUTION OF THE U.S.P.H.S. RECOMMENDED LIMIT OF 500ppm TOTAL DISSOLVED SOLIDS FOR EACH WATER TYPE, EXPRESSED IN Meq/ℓ

③ INDICATES THE U.S.P.H.S. RECOMMENDED LIMIT FOR THE CONCENTRATION OF A PARTICULAR ION

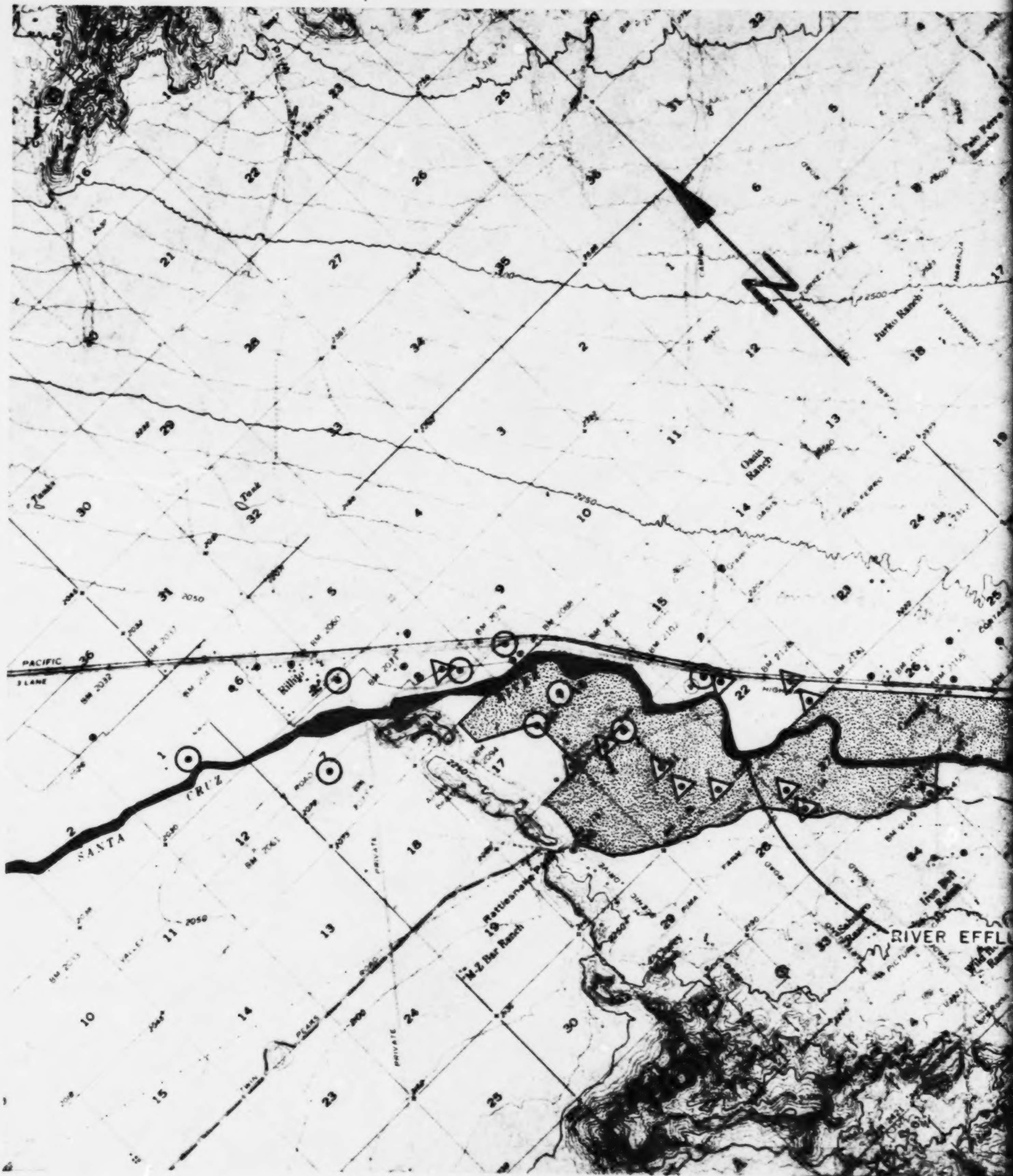
④ REPRESENTATION OF THE CROSS SECTION OF A TYPICAL WELL SHOWING DEPTH AND WATER LEVEL

CITY OF TUCSON WATER AND SEWER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

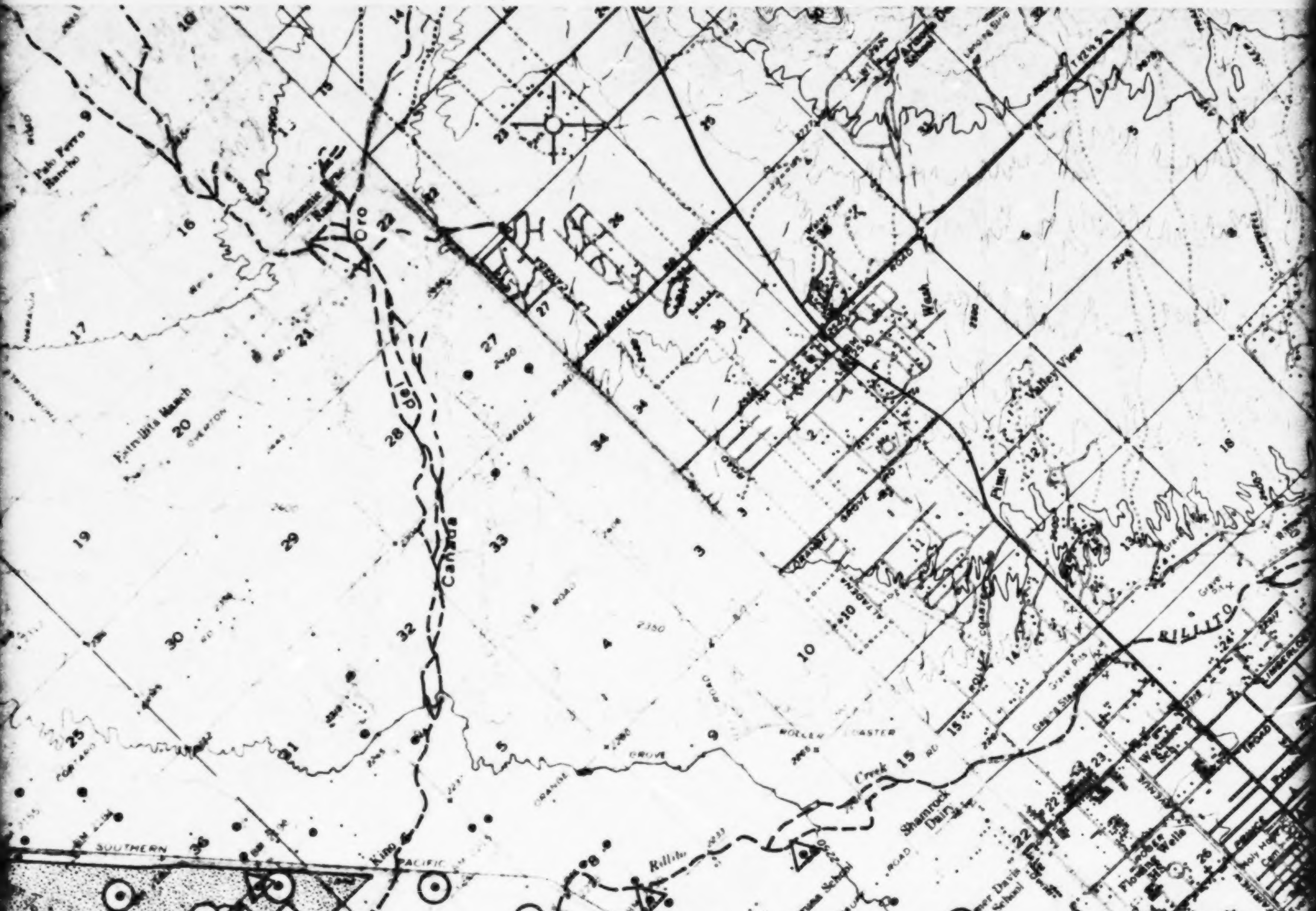
CHEMICAL QUALITY MAP

JULY 1966 SCALE: 1 INCH = 1 MILE **FIGURE 9**



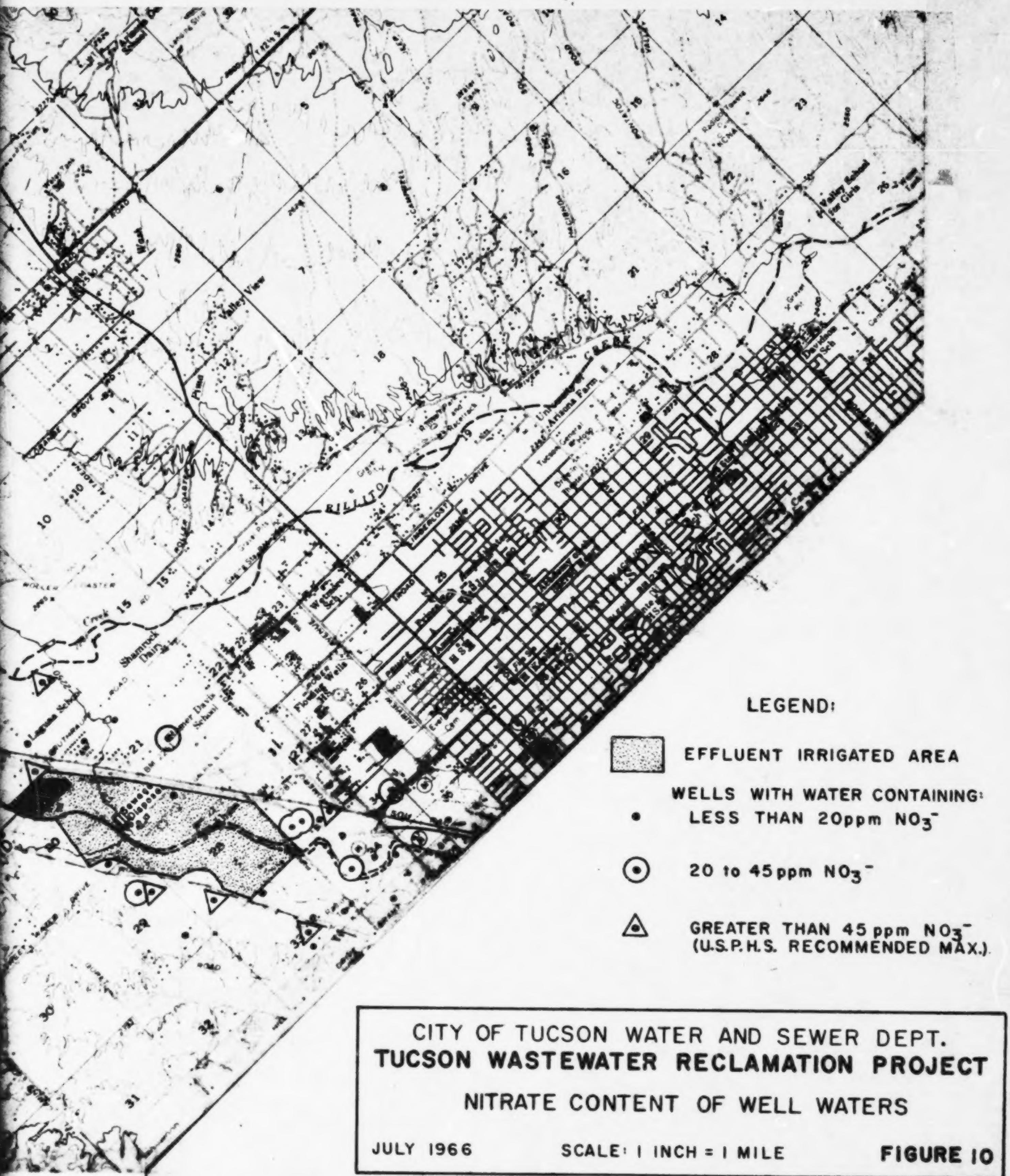
N
PACIFIC
SANTA
CRUZ
RIVER EFFL
Oasis Ranch
Jurko Ranch
M-Z Bar Ranch
Rattlesnake
Tank
Tank
2500
2250
2050

A


R EFFLUENT RECHARGE REACH
EFFLUENT HOLDING POND
SANTA CRUZ
Cañada del Oro
Rillito
Creek
RILLITO
Valley View
Sunset Dairy
Shamrock Dairy
SOUTHERN PACIFIC
ROLLER COASTER
ORANGE GROVE
Estrellita Ranch
Palo Verde Rancho
Sweetwater Ranch
Flowing Wells
Laguna School
Homer Davis School
RANGE
CIT
TUCSO
JULY 19

7

41


Valley View
RILLITO CREEK
University of Arizona Farm
Tucson General Hosp
Valley School for Girls
Davidson Sch
Shamrock Dairy
Flowing Wells
Laguna School
Homer Davis School
Sewage Disposal

LEGEND:

▨ EFFLUENT IRRIGATED AREA

WELLS WITH WATER CONTAINING:

- ● LESS THAN 20ppm NO_3^-
- ⊙ 20 to 45ppm NO_3^-
- △ GREATER THAN 45 ppm NO_3^- (U.S.P.H.S. RECOMMENDED MAX.)

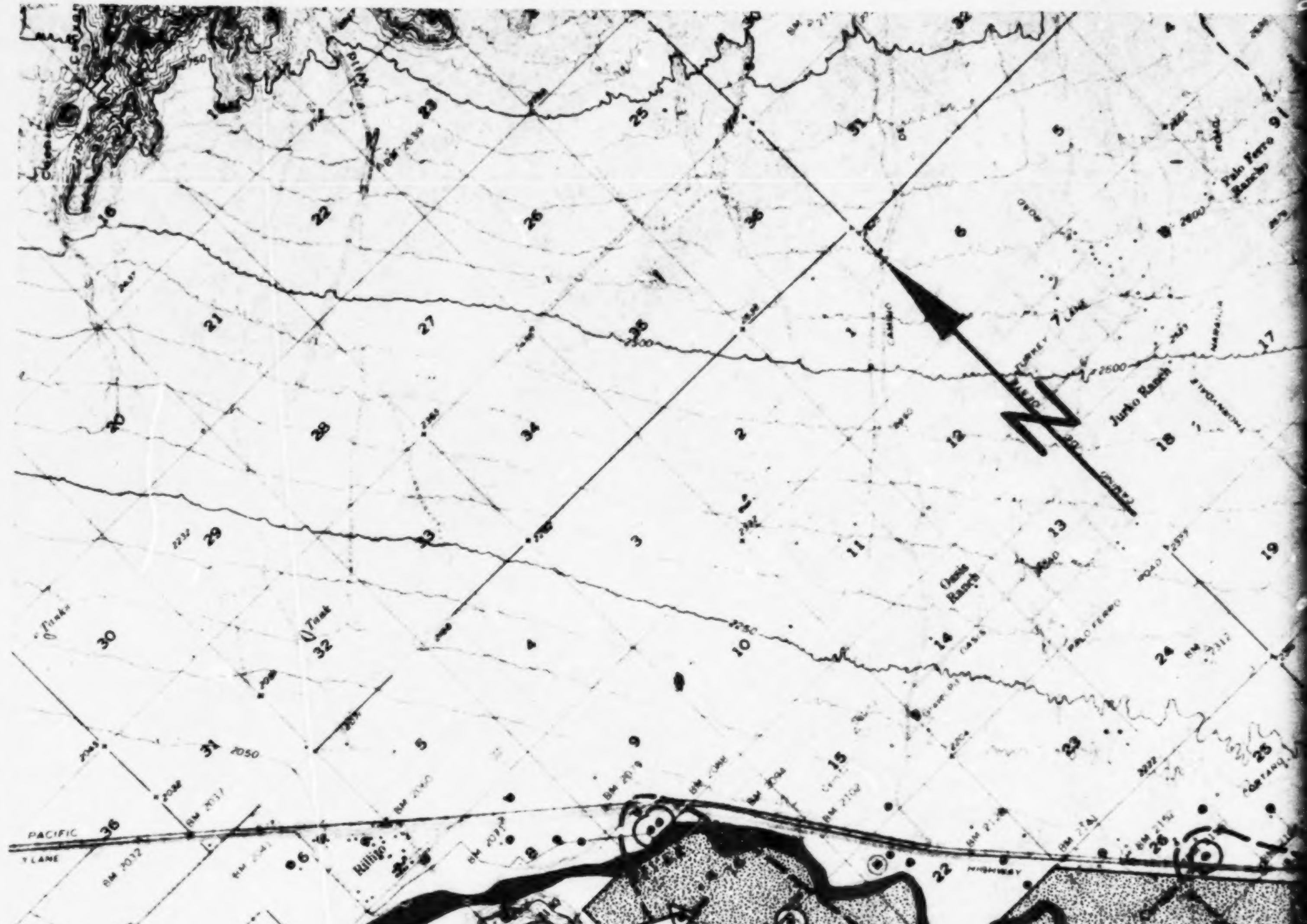
CITY OF TUCSON WATER AND SEWER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

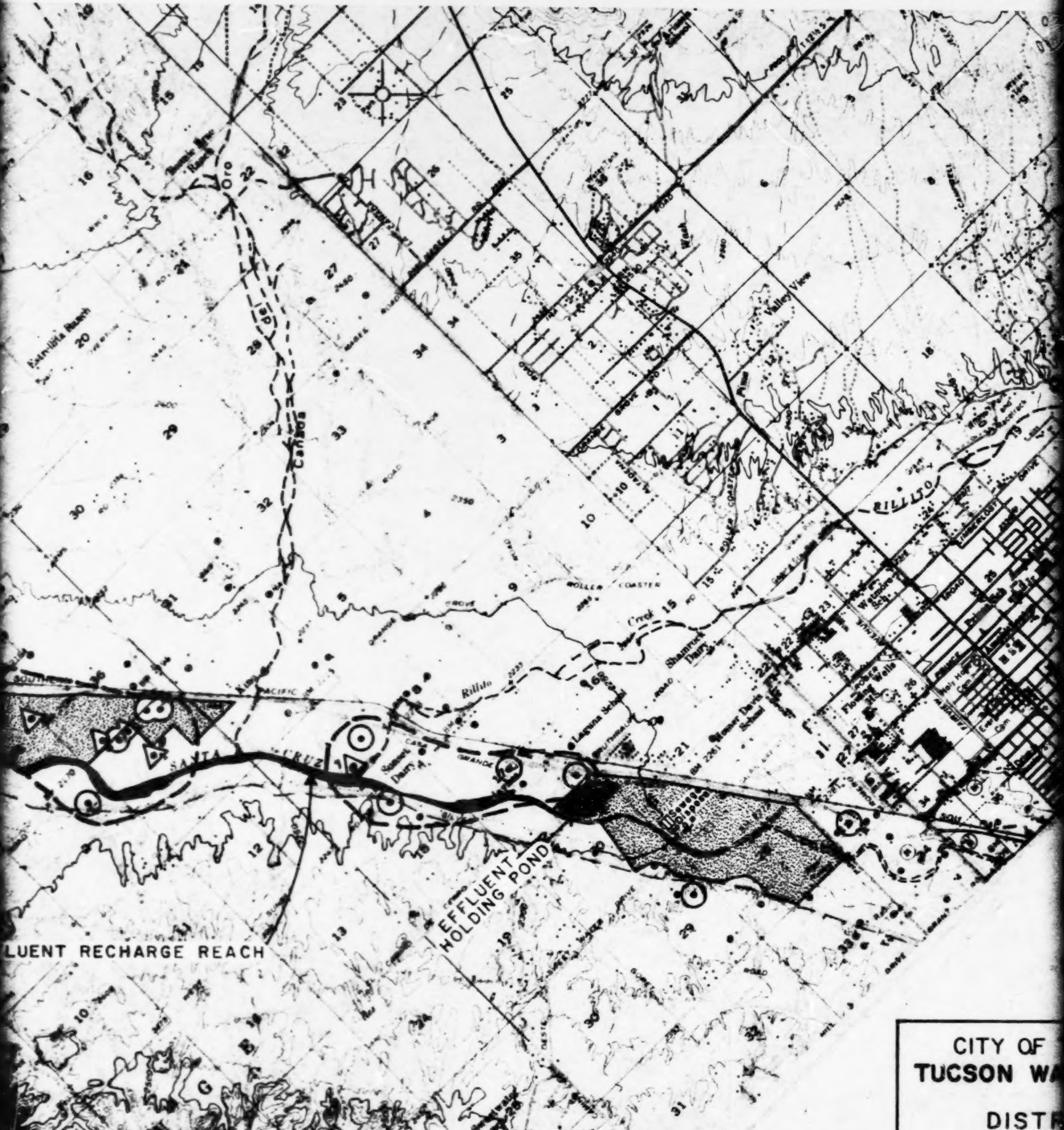
NITRATE CONTENT OF WELL WATERS

JULY 1966 SCALE: 1 INCH = 1 MILE **FIGURE 10**

C

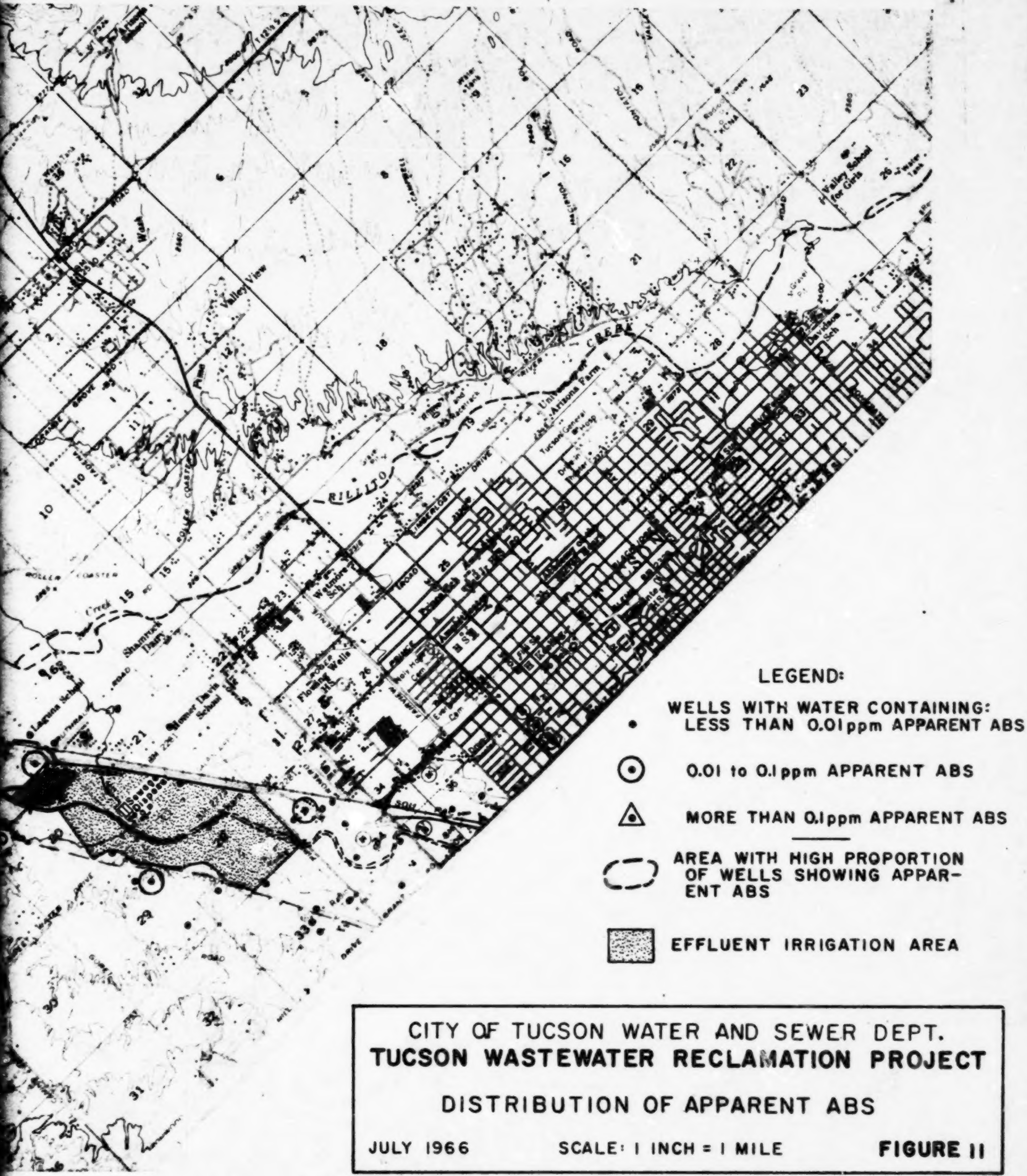


Palo Ferro Ranch
Jurko Ranch
Oasis Ranch
PACIFIC
LANE
HIGHWAY
SANTA CRUZ
VALLEY
ROAD
PRIVATE
Rattlesnake
M-Z Bar Ranch
Iron Mill Ranch
RIVER EFFLU
2500
2050


LUENT RECHARGE REACH
EFFLUENT HOLDING POND
SANTA
CRUZ
Rillito
RILLITO
Cañada del Oro
Creek
ROLLER COASTER
GROVE
Valley View
Shamrock Dairy
Laguna School
Flowing Wells
SOUTHERN PACIFIC

CITY OF
TUCSON WA
DISTR
JULY 1966

B


LEGEND:
● WELLS WITH WATER CONTAINING: LESS THAN 0.01ppm APPARENT ABS
⊙ 0.01 to 0.1ppm APPARENT ABS
△ MORE THAN 0.1ppm APPARENT ABS
AREA WITH HIGH PROPORTION OF WELLS SHOWING APPARENT ABS
▨ EFFLUENT IRRIGATION AREA
RILLITO
CREEK
Valley View
Valley School for Girls
University of Arizona Farm
Tucson General Hosp
TUCSON
Wetmore Sch.
Flowing Wells
Shamrock Dairy
Laguna School
Homer Davis School
Sewage Disposal
ROLLER COASTER
Creek

CITY OF TUCSON WATER AND SEWER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

DISTRIBUTION OF APPARENT ABS

JULY 1966 SCALE: 1 INCH = 1 MILE **FIGURE 11**

C

seasonal variation as well as variations with volume or pumpage.

4.05 BACTERIOLOGY OF WELLS by Robert A. Phillips, Ph. D.

Water was collected from source outlet after appropriate flaming of same by means of a portable propane torch. The pyrex collecting bottles (500 ml) were laboratory sterilized by autoclaving with aluminum covers in place and the collected samples were preserved in the field in an ice water bath for transportation to the laboratory.

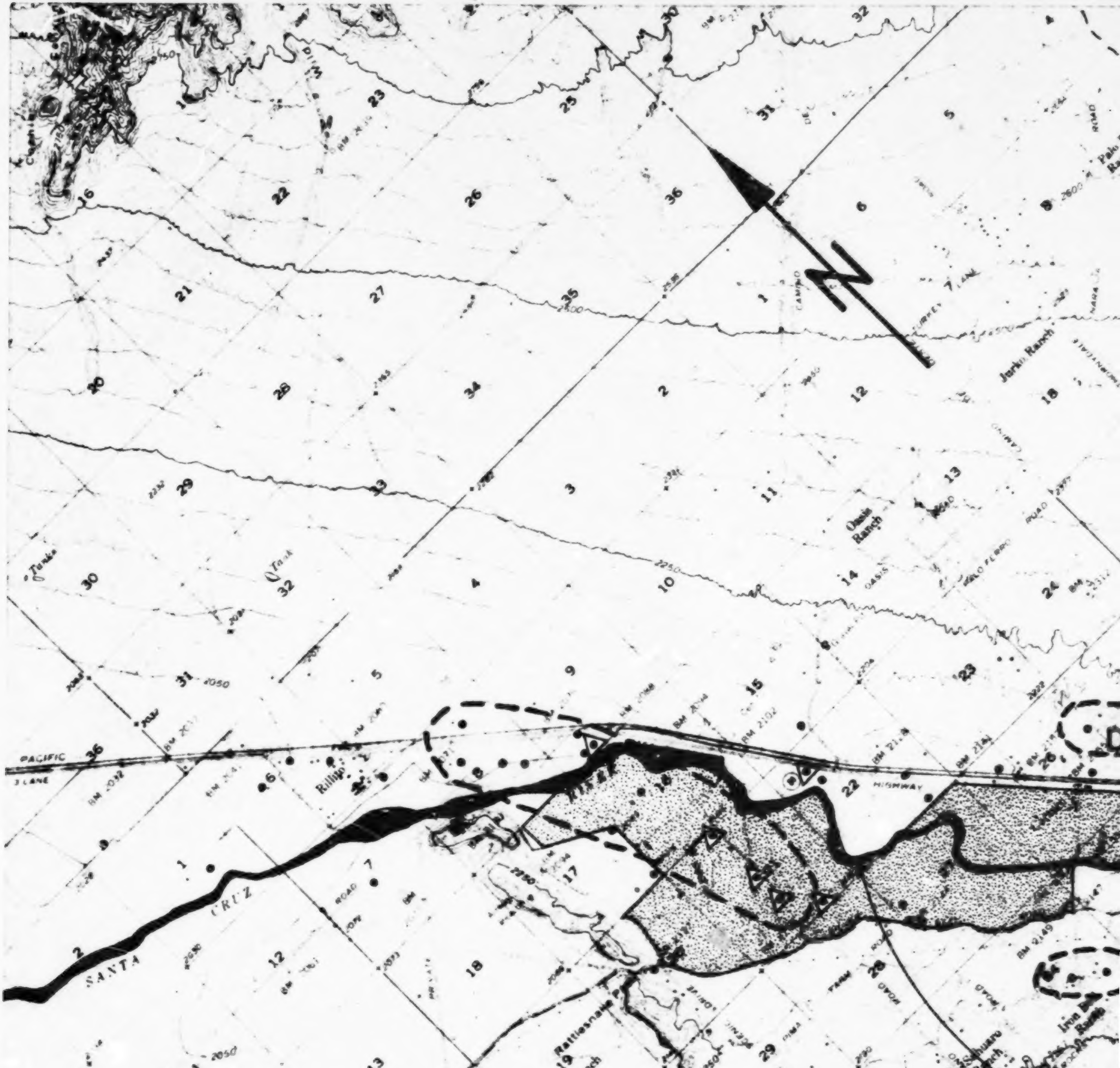
Incoming samples were immediately plated, millipore filtered for Bacterium Coli and Fecal Streptococci, and incubated with the lactose fermentation tubes for gas production, in the usual bacteriological procedures.

Bacteriological analyses of well waters, during the first year's efforts, have been concentrated upon assessing the bacteriological quality of well waters throughout the study area. The locations of these wells are shown in Figure 12.

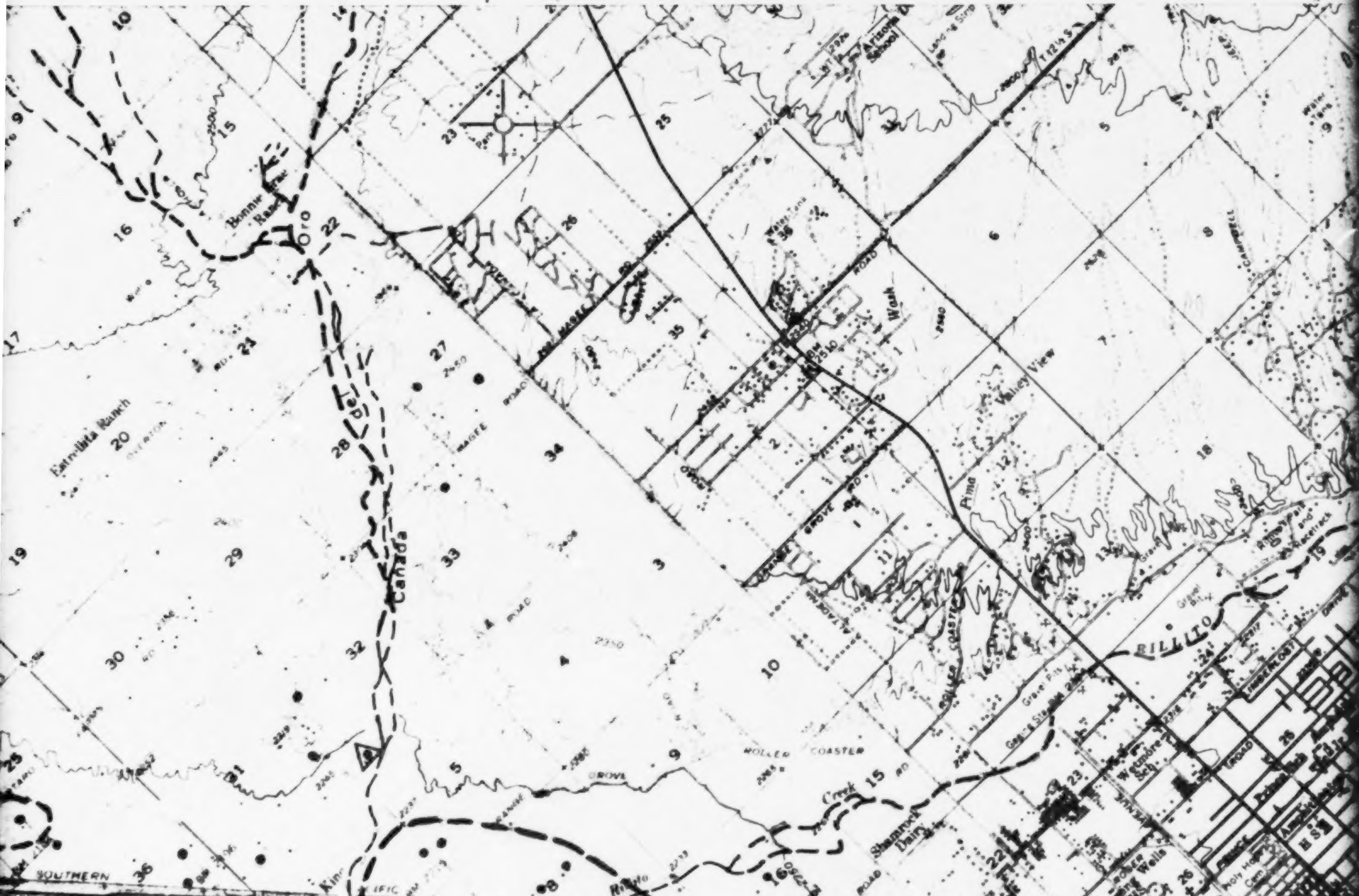
Prior to June 1966, at least one sample had been taken from each of 109 different wells with a total of 202 samples analyzed. During June-July 1966, a resampling of the entire area was done, repeating analyses on 82 of the above wells and using expanded analytical procedures. The remaining wells were not sampled for various reasons--no access, well abandoned, or as in the case of irrigation wells, not in operation. Several wells were not re-sampled because of sampling difficulties.

For the first 202 samples, the analyses made on each and the media were as follows:

1. Standard Plate Count (Standard methods agar)
    a. 20° C, 48 hours.
    b. 35° C, 24 hours.



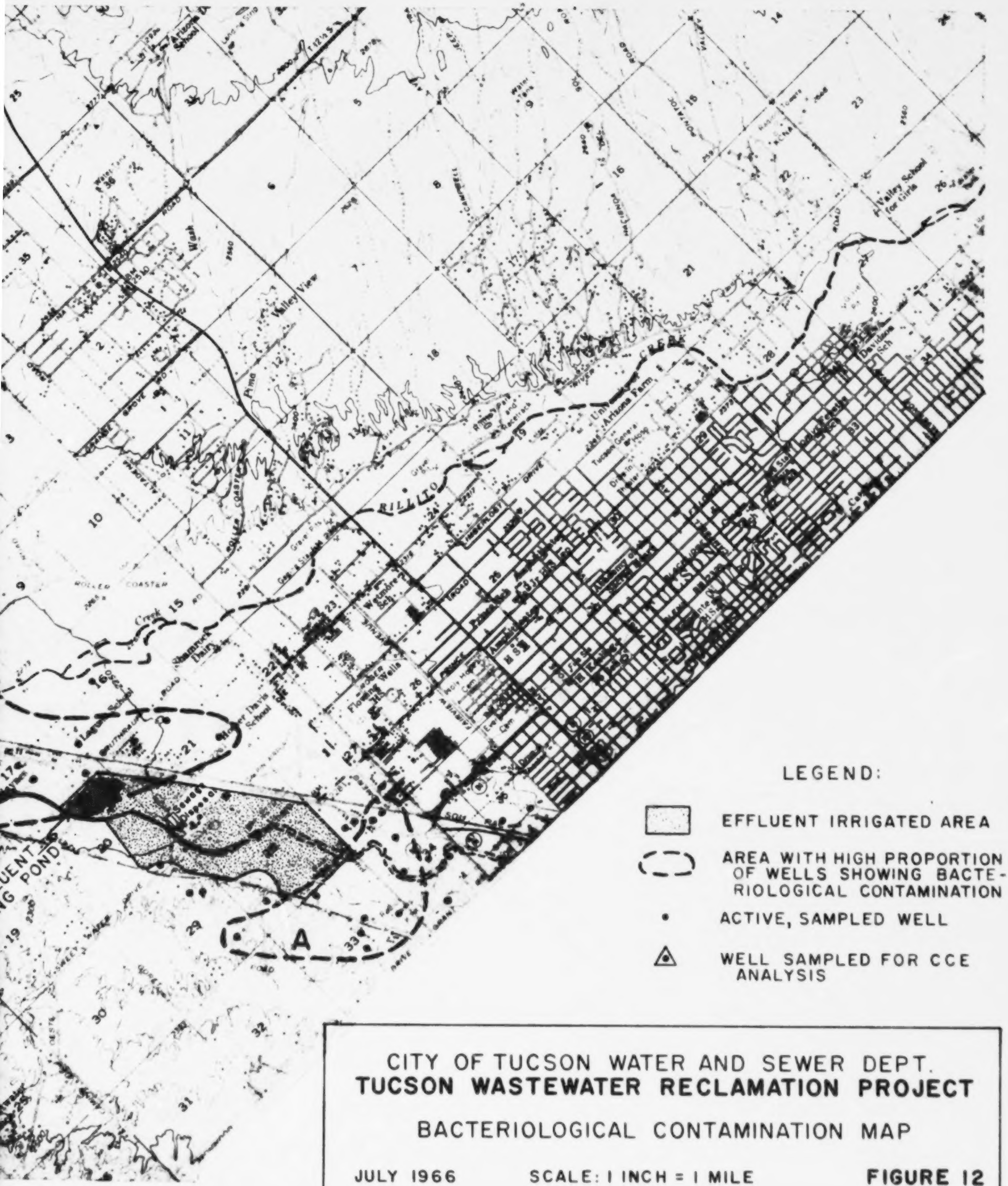
N
PACIFIC
3 LANE
HIGHWAY
SANTA
CRUZ
RIVER
Rillito
Jarko Ranch
Oasis Ranch
Rattlesnake
M-Z Bar Ranch
CAMINO
ROAD
OASIS
PALO VERDE
PRIVATE
PIMA
FARM
VALLEY
PLANS
RIVER EF


Estrellita Ranch
Oro
Canada del
Canada
ROLLER COASTER
GROVE
SOUTHERN
PACIFIC
SANTA CRUZ
Sunset Dairy
CASA GRANDE
SILVER
Shamrock Dairy
Rillito
Creek
RILLITO
Pima
Wash
Valley View
Wetmore Sch
Flowing Wells
Sewage Disposal
EFFLUENT HOLDING POND
FLUENT RECHARGE REACH
A

CITY OF TUC
TUCSON WAST

BACTERIOL

JULY 1966 S


LEGEND:
▨ EFFLUENT IRRIGATED AREA
AREA WITH HIGH PROPORTION OF WELLS SHOWING BACTERIOLOGICAL CONTAMINATION
● ACTIVE, SAMPLED WELL
◬ WELL SAMPLED FOR CCE ANALYSIS
RILLITO
CREEK
Valley View
Pima
Arizona Farm
Davidson Sch
Valley School for Girls
ROLLER COASTER
Shamrock Dairy
Sewage Disposal
A
EFFLUENT
POND

CITY OF TUCSON WATER AND SEWER DEPT.
TUCSON WASTEWATER RECLAMATION PROJECT

BACTERIOLOGICAL CONTAMINATION MAP

JULY 1966 SCALE: I INCH = I MILE **FIGURE 12**

2. Membrane Filtration (100 ml volumes)
    a. Coliform group (M-coliform broth)
    b. Fecal Streptococci (M-enterococcus agar)
3. Multiple Dilution (One 10-ml and one 1-ml portions)
    a. Coliform group (Lactose broth and BGB)
    b. Fecal streptococci (Azide dextrose broth and ethyl violet Azide broth).

In the last 82 samples, fecal coliforms were determined using the method of Geldreich, E. E. et al.[1] The multiple tube method was changed to five 10-ml portions and one 1-ml portion. For wells having known high contamination, smaller volumes were filtered, and greater five tube dilutions were used.

Of the 109 wells first surveyed, 74 showed no evidence of either coliform bacteria or fecal streptococci by either membrane filtration or the multiple dilution method. Ten wells showed the presence of coliforms or fecal streps in all analyses. Twenty-five wells gave erratic results in repeated sampling.

Using the membrane filter method, 32 samples showed contamination by coliforms and fecal streptococci. In 23 samples, only coliforms were detected; only fecal streptococci were detected in 20 samples.

In general, the membrane filter method was superior to the multiple tube method because of the larger inoculation volumes. However, for 15 samples, even though only one 10-ml portion was used, there was confirmed coliform growth but a failure to show growth by the membrane filter method. Only three samples produced this failure between the membrane filter and the broth test for the streptococci.

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[1] Geldreich, E. E., et al. Fecal-Coliform-Organism Medium for the Membrane Filter Technique. JAWWA, 57:208 (1965).

In the re-survey of 82 of the wells during the peak of the irrigation season, 35 wells showed contamination by at least one of the tests or one of the indicator groups to which the fecal coliform test was added.

Membrane filtration produced the following results:

Groups Detected	Number of Analyses
Coliforms alone (C)	14
Fecal streptococci alone (FS)	4
Fecal Coliforms alone (FC)	0
C + FS	11
C + FC	3
FS + FC	0
C + FS + FC	3
Number of contaminated wells	35
Number of non contaminated wells	47
Total Wells	82

The multiple dilution method (five 10-ml portions and one 1-ml portion) showed six other cases of contamination by either coliforms or fecal streptococci or both which were not detected by membrane filtration.

Figure 12 shows those areas where a high proportion of the existing wells show contamination by one or more groups as determined by one or more methods. Contamination is not limited to these areas, nor are all wells within these areas contaminated.

In general, effluent irrigation and effluent recharge in the river channel can be thought of as the origins of this contamination. Particularly for the irrigation wells, construction and use purposes are such that there is little consideration given to sanitary protection of these wells. Other sources are those of local waste disposal such as that in Area "D" which arises from wastes from a dairy and farm complex. Area "A", though shoutheast of the irrigated areas, is a region of high contamination; however, the source is not evident. Other sources of contamination in individual cases are horse corrals, cattle herds, septic tanks, and surface drainage.

For the coming year a sampling program covering 30 project wells will be implemented on a tri-annual basis. The samples will be taken prior to and at the end of the irrigation season, and at mid-off-irrigation season.

CARBON CHLOROFORM EXTRACT (CCE) METHOD

Equipment was constructed for concentrating organic substances in well waters by the carbon adsorption method (CAM). Two of these units were built, modified several times each and used successfully.

Water is pumped through the carbon columns at a rate of 100-120 ml/min for 10 days. This gives a total volume of about 350 gallons. The column was packed with plus 30-mesh activated carbon previously extracted with chloroform.

The carbon filters were returned to the laboratory at the end of the run and the carbon placed in Pyrex drying trays to remove moisture. The carbon was then stored in wide-mouth Mason jars until the necessary equipment was set up for chloroform extraction.

Sampling difficulties have, for the most part, necessitated the selection of irrigation wells. In turn, sampling is then limited to the irrigation season and the irrigator's pumping schedules. To date, ten wells as shown in Figure 12 have been sampled, and the carbon columns are being processed.

In general, the procedures for the analysis is that outlined in Standard Methods, Twelfth Edition, 1965. The sampling procedure used is the modification proposed by Booth, et al,[2] using a 100-120 ml/min sampling rate for a total volume through the column of about 400 gallons.

4.06 MICROBIOLOGY AND VIROLOGY OF WELLS

Microbiological tests conducted to establish viruses in project well waters are not as routinely run as the chemical and bacteriological tests discussed above, however, they are being used to back up data on wells which show indication of contamination by other parameters.

Four samples from wells within the effluent recharge area were collected for virus and Salmonella studies. The sedimentation of the water samples was placed in the appropriate tissue cultures and attempts to isolate enteric viruses were unsuccessful. The group responsible for the pathogenic bacterial studies cultured the low speed sediment material of these same water samples which resulted in the isolation of one Salmonella species from one well sample.

The swab-gauze pad technique was followed as before. In the coming years, a well sampling program has been designed to corroborate the bacteriology in case of repeated positive sample results, and will be heavily influenced by the findings of the sanitary survey. Utilizing the multiple-millipore technique will permit rapid processing of "grab samples" from project area wells and therefore a greater number of wells may be sampled because of the collection method.

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[2] Booth, R. L., et al. Evaluation of Sampling Conditions in the Carbon Absorption Method. JAWWA, 57:215 (1965).

CHAPTER 5

PILOT FILTER SYSTEM

5.01 INTRODUCTION

During 1964, personal extensive research was conducted on wastewater reclamation activities and pertinent literature, and concluded, in a report entitled "A Feasible Plan for Recreational Use of Reclaimed Water in Tucson," that horizontal flow sand filtration tertiary treatment would be the desirable method in a preliminary approach to the reclamation of Tucson wastewater. The filter system proposed in that report called for use of 80,000 cubic yards of high permeability natural river sands and gravels placed in a silt lined trapazoidal excavation with surface dimensions 600 x 350 feet, to a depth of 20 feet, and three to one side slopes. Six x 1/2 acre spreading basins were to provide 1 to 1.5 MGD tertiary filtered effluent for recreational purposes in man-made lakes.

A review and discussion of this proposal with local health officials, University personnel, and other interested parties led to the preparation and submission, early in 1965, of an application for a demonstration project grant request. The pilot plant was described therein as follows:

> The pilot plant will consist of two artificially constructed spreading basins feeding into horizontal sand and gravel filters which supply effluent to four test ponds. Locally occurring materials will be used to construct the spreading basin and filter. Field testing of this material has already been performed. The filter and succeeding ponds will be separated by a collection trench which will include sampling facilities and

provide a detention time for chlorination. Two parallel test facilities will be constructed. Major differences in the two units will include different methods of sealing, in addition to the provision for varying the travel distance in the filters. Piping facilities will be designed to provide complete flexibility in operation. This will include the provision for taking effluent from an existing 42-acre holding pond, currently receiving secondary effluent, or using the effluent directly.

The pilot spreading basins and filters were designed on the basis of 100,000 gallons per day per unit, and will provide travel distances ranging from 90 to 150 feet. It is anticipated that this flow can be applied on an alternating day schedule since the spreading basins will be surfaced with six inches of pea gravel. Should this loading prove to be practical, approximately one acre of spreading basin will be required per million gallons a day in the scale-up reclamation-recreation project.

Following grant approval (June,1965) and initiation of detail project design, the Technical Committee unanimously agreed to the construction of one enlarged, plastic lined, filter facility with provisions for horizontal travel distances up to 250 feet instead of much smaller parallel filters as described in the plant operation section of the grant request.

5.02 PHYSIO-BIOCHEMICAL ACTIVITY

The spreading basins and horizontal filter unit are the key to the tertiary treatment system. Proper understanding of the operation and its optimization is essential to insure improved quality of the final effluent. Anticipated effects of the filter unit with regards to changes in chemical, biological and virological characteristics of the reclaimed water are summarized in the following statements:

1. Biological activity in the near surface (1-3 feet) portion of the filter below the spreading basin, where the percolate flows mainly in a vertical direction, may be maintained aerobic by intermittent operation, while the downstream portions, where flow is mainly horizontal, may become anaerobic.
2. Nearly complete reduction in soluble 5-day B.O.D. and C.O.D. can be accomplished after only a few feet of travel through an aerobic sand filter.
3. Biodegradation of the apparent alkyl benzene sulfonate is accomplished in the aerobic type sand filter resulting in 70-90% removal. As the "soft" detergents (LAS) become available, the problem should correct itself with less difficulty.
4. An aerobic filter media condition enhances nitrification which is likely to lower the p^H. This lowering of $_pH$ may, in turn, cause filter matrix dissolution and a reduction in percolate alkalinity. Perhaps a p^H rise from the oxidation pond activity may compensate the foregoing $_pH$ depression with end result of $_pH$ at or near seven (7).
5. Should anaerobiasis prevail in the downstream area of the filter, denitrification may occur and the resultant nitrate (NO_3) build up could produce a source of oxygen for facultative filter organisms. Therefore, with a NO_3 oxygen supply, the reduction of sulfates will be inhibited. Final filter effluent should not be expected to be a lake hazard because of high nitrate nutrients.

6. Phosphate removal might also be derived from this filter activity though the actual mechanism is vague.
7. Total dissolved solids (TDS) in filter effluent should mirror the TWTP activated sludge effluent, though the distribution proportion and chemical nature may be altered.
8. The bacteriological quality, as indicated by experience, of water subjected to slow sand filtration is superior to most other natural means of filtration. However, the travel time factor must be determined for any proposed unit, and the anticipated detention time in the filters is of the magnitude of one to three days. This period of time and distance suitable for coliform removal should also cause virus degradation.
9. Because it seems technically feasible to maintain aerobic and anaerobic regions in this filter operation, a superior quality tertiary filter effluent from the chemical, biological, and virological standpoints will be anticipated.
10. The reclaimed water will be ponded in small open reservoirs. Water losses from evaporation, seepage, and regulated releases will occur. Effects of prolonged storage as an open water body will be evaluated in terms of physical, chemical, bacteriological, and virological parameters. Any resusitation or regrowth of microscopic organisms can be detected by this study. An introduction of fresh water fish and other aquatic life will be used to illustrate the nature of the reclaimed water and evaluate any further treatment that may be required.

By evaluation of the tertiary treatment system, it will be possible to determine the degree of treatment necessary to insure the safe introduction of the reclaimed water into the water economy of the Tucson region.

5.03 PRE-CONSTRUCTION INVESTIGATIONS

Construction of the 42-acre irrigation holding pond during 1964 provided subsurface information supplementary to a number of test borings made by the Arizona State Highway Materials Division within the area. The excavation and borings generally showed silt from 0-4 feet, sandy clay from 4-7 feet, and from 7-18 feet sand, gravel, and some clay. Physical properties of the materials by depth are as summarized in the following:

Depth Range Feet		Swelling 48 Hours	Per Cent Passing Sieve No. 200	40	10	4	1
0 - 4	Average	0.06	75	90	98		
	Range	0.02-0.12	60-90	85-95	95-100	-	-
4 - 7	Average	0.03	50	70	90	100	
	Range	0.02-0.06	30-70	50-90	80-100	100	-
7 - 18	Average	0.01	3	25	47	60	90
	Range	0.00-0.02	1-7	10-40	30-65	50-70	80-100

In the immediate area of proposed filter construction four 20-foot deep sampling trenches were excavated to permit inspection and to provide large samples of underlying sand and gravel for field and laboratory permeability and grain size analysis.

A total of 22 mechanical analyses and permeability tests were run on representative samples of gravel and sand materials to be used for the filter media.

Representative two cubic yard samples of available test trench sands and gravels were collected from the trench side walls with a front end loader and transported to the test trough area for stock piling.

For each test the trough (See Fig. 15) was hand loaded with shovels and a wheel barrow in approximately 6-inch lifts and compacted by tramping underfoot.

Secondary sewage effluent was applied by siphon to the intake reservoir and a constant level maintained by use of an overflow. Initially some effluent was poured slowly over the test material surface to insure compaction and to hasten saturation.

The outflow was monitored volumetrically at short intervals following intake level stabilization and a final test value obtained after about two hours of constant rate outflow.

The test trough outlet was initially fitted with a screen which permitted "free discharge ". In order to provide an absolute measurement of hydraulic gradient the "free discharge" drum unit was removed and replaced by the "flooded discharge" drum unit.

The "test trough slope" was determined by measuring the difference in end elevation in the initial "free discharge" test runs. For subsequent "flooded discharge" tests, the elevation difference was measured between intake pond level and outlet pond level. Most field permeability tests were run with 8% to 10% slope.

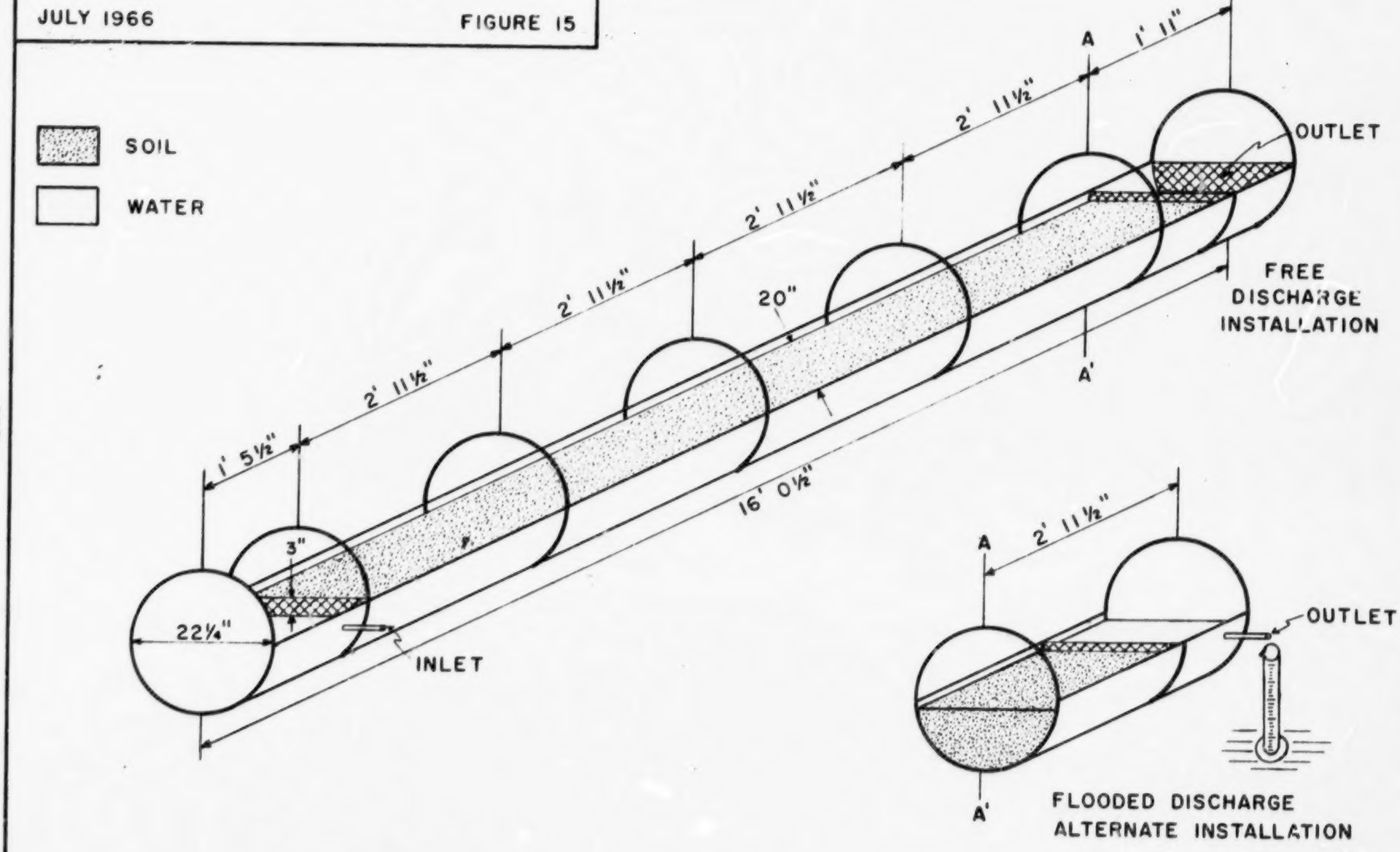
A sample calculation of coefficient of permeability from field test trough data dollows:

From Darcy's Law:

$$Q = K\,I\,A \text{ and } K = \frac{Q}{I\,A}$$

Where: Q = Quantity of flow per unit of time.
I = Hydraulic Gradient through the soil.
A = Cross-sectional area of soil through which flow occurs.
K = Coefficient of permeability.

TUCSON WASTEWATER RECLAMATION PROJECT
FIELD PERMEABILITY APPARATUS
JULY 1966 FIGURE 15


▨ SOIL
☐ WATER
A
1' 11"
2' 11½"
2' 11½"
2' 11½"
2' 11½"
1' 5½"
OUTLET
FREE
DISCHARGE
INSTALLATION
A'
20"
16' 0½"
3"
22¼"
INLET
A
2' 11½"
OUTLET
A'
FLOODED DISCHARGE
ALTERNATE INSTALLATION

Using results of a typical field test as an example:

Q = "Stabilized outflow Rate" - 475 milliliters per minute or 24.16 cu. ft. per day

I = "Testtrough slope" - $\frac{1' \quad -4''}{13' \quad -9''}$ X 100 - 9.1 percent

A = "Cross-sectional Area" -2.0 square feet

$$K = \frac{24.16 \text{ ft}^3/\text{ day}}{(0.091 \text{ ft/ft})\ (2.0 \text{ ft}^2)}$$

$$= 132.5 \text{ ft}^3/\text{ft.}^2/\text{day}$$

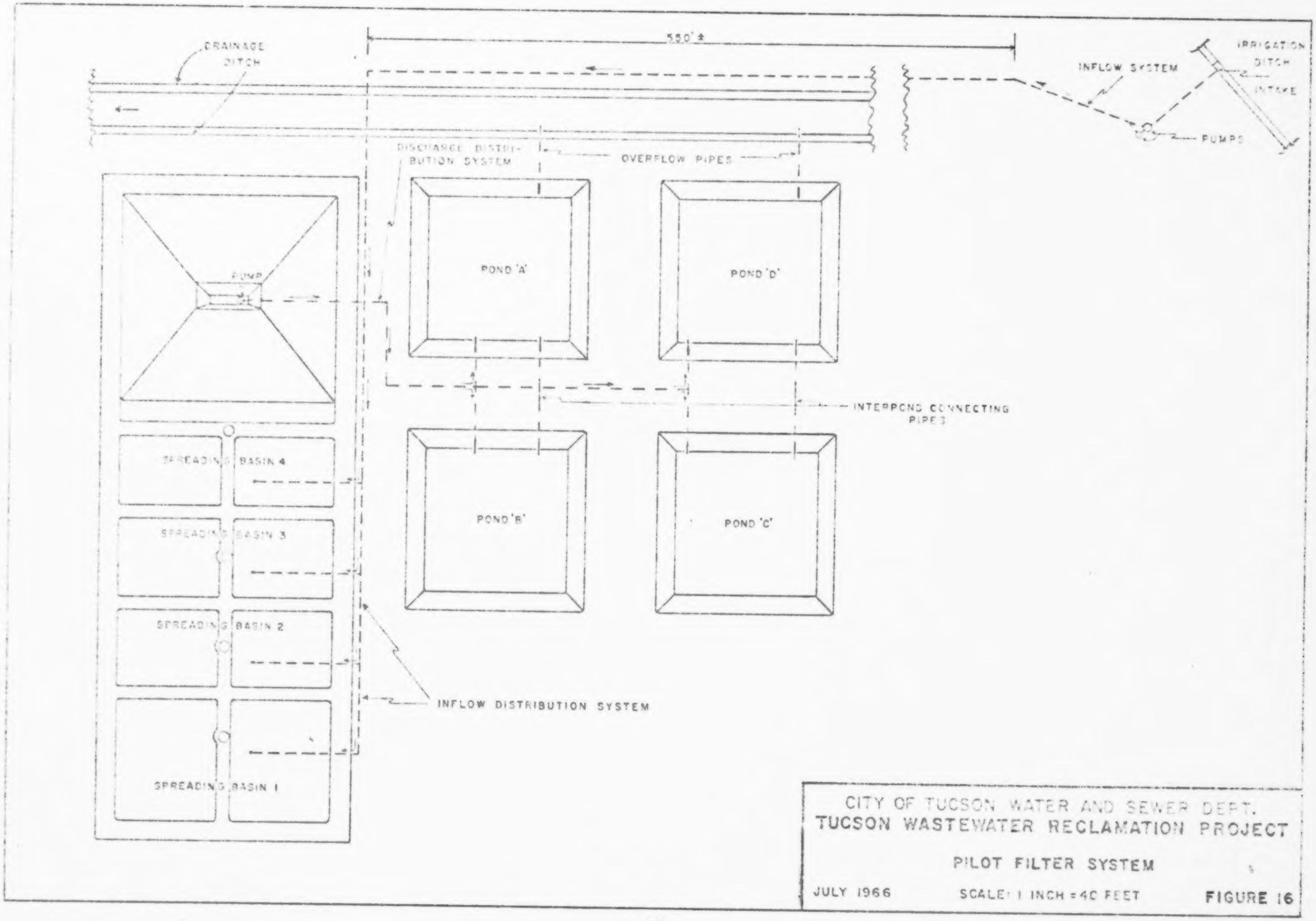
The results of this testing confirmed the suitability of the natural river materials for use as filter media. The tabular data will be published in a subsequent report along with test data obtained during construction; much of which has yet to be analyzed.

5.04 DESIGN SPECIFICATIONS

The pilot filter was designed to accommodate approximately 100,000 gallons of secondary effluent per day intermittantly applied on four spreading basins with total area of 1/2 acre. A discharge of 70 G.P.M. at the collection trough was anticipated when spreading occurred at mid-point of the filter. A total of 88 sampling lines and 12 sampling pans, eminating from four axially aligned collection wells, provide filter monitoring vertically at six levels every three feet and horizontally at 50 foot intervals. Details of the filter and sampling lines are shown on Plates 6 and 7. The pilot filter system layout, including demonstration fish ponds and associated pumping and piping, is sketched on Figure 16.

5.05 CONSTRUCTION

Actual pilot filter construction began in October 1965 with a contract including grading, filter and pond excavation, and protective dike


DRAINAGE DITCH
550' ±
INFLOW SYSTEM
IRRIGATION DITCH
INTAKE
PUMPS
DISCHARGE DISTRIBUTION SYSTEM
OVERFLOW PIPES
PUMP
POND 'A'
POND 'D'
POND 'B'
POND 'C'
INTERPOND CONNECTING PIPES
SPREADING BASIN 4
SPREADING BASIN 3
SPREADING BASIN 2
SPREADING BASIN 1
INFLOW DISTRIBUTION SYSTEM

CITY OF TUCSON WATER AND SEWER DEPT.
TUCSON WASTEWATER RECLAMATION PROJECT

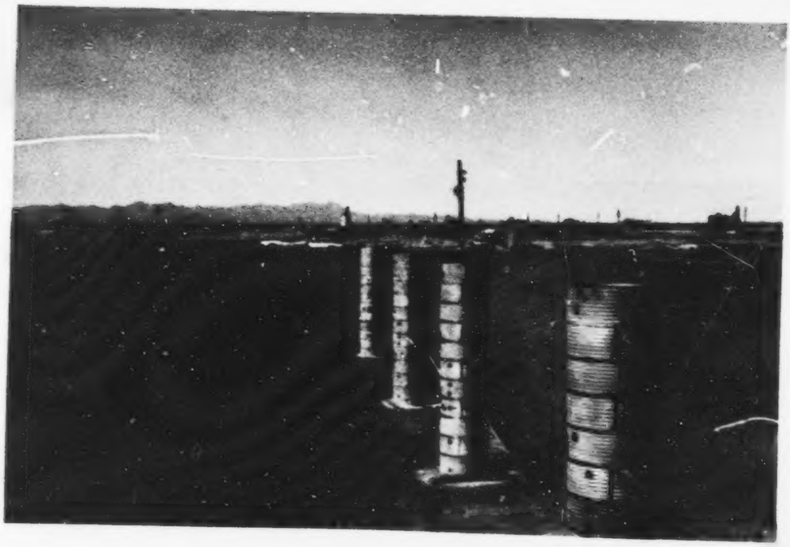
PILOT FILTER SYSTEM

JULY 1966 SCALE: 1 INCH = 40 FEET **FIGURE 16** construction. A second contract for borrow pit excavation and filter backfill extended over March and April 1966. All remaining portions of the work were performed by Tucson Water and Sewers Department personnel. The revised filter construction schedule is included as Figure 17.

Following excavation, the entire filter was lined with one foot of compacted silt overlaid by 10 mil polyethylene plastic sheeting joined and sealed with polyethylene tape to provide a near water tight bottom. Sampling wells are five foot diameter corregated metal pipe, with riveted and soldered joints and seams, mounted in a concrete "doughnut" beneath the plastic liner (Plate 1). Sampling well drainage was provided through the bottom filled with coarse gravel overlying the sand and gravel sub-grade.

Filter media was placed in approximately three foot lifts by heavy earth moving equipment and homogenized in place (Plate 2). Sampling lines are made up of gravel packed 2-inch I.D. ten foot perforated PVC pipe joined through adapters to variable lengths of 3/4-inch I.D. PVC pipe terminating in 3/4-inch steel half couplings welded to inlets at appropriate depths and angles in the sampling wells (Plate 3A). The internal and peripheral dikes are constructed of earthen cores covered with polyethylene sheeting and topped with 1 1/2-inch graded gravel. Nine inches of 1 1/2-inch graded gravel was used to deck the spreading basins (Plate 3B).

The filter face is stabilized with 3-inch gravel over boulders set on a 12 foot concrete slab to earth keylock. Collection trough slopes are veneered with 1 1/2-inch graded gravel (Plate 4A).



A - Sampling Wells in Place
Silt Lining Complete

B - Placing of Plastic Sheeting
and Filter Media

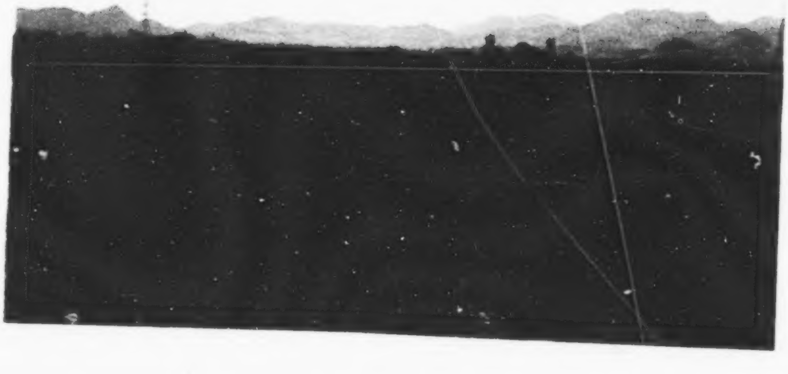
Plate 1

A - Building up Filter Media

B - Mixing Filter Media in Place

Plate 2

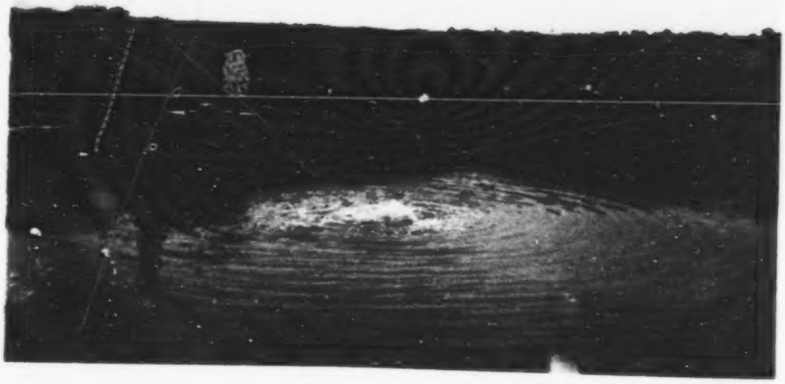
A - Installation of PVC Sampling Lines



B - Spreading Basins Finished With Gravel

Plate 3

A - Collection Trough Partially Completed
Initial Flow of Water Through Filter



B - Secondary Effluent Being Pumped
into Spreading Basins

SCHEDULE OF CONSTRUCTION FOR TUCSON WASTEWATER RECLAMATION STUDY
FILTER FACILITY

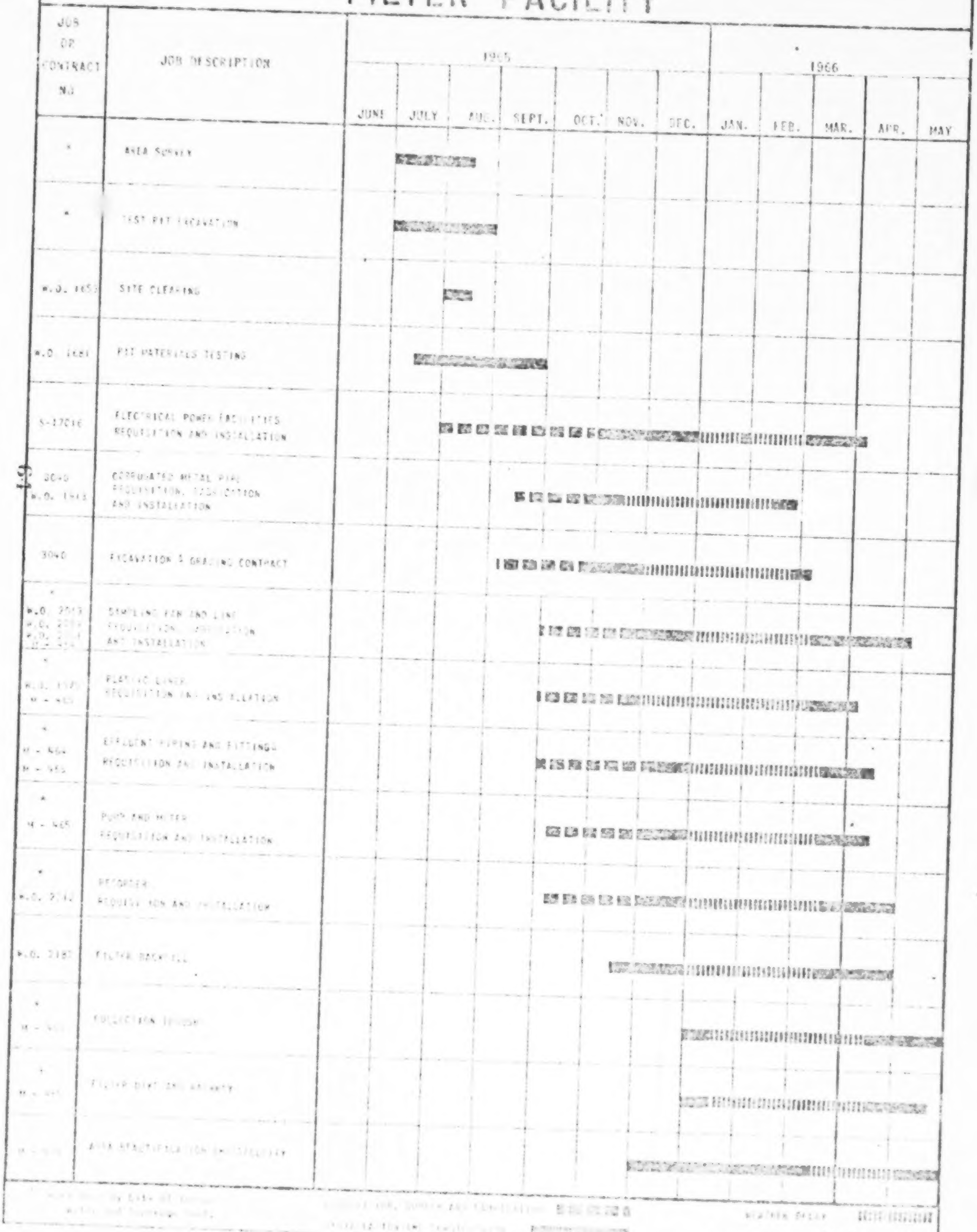


FIGURE 17

The metered influent line is 8-inch cement asbestos from twin pumps manually controlled to individually valved spreading basins, (Plate 4B). Effluent is automatically pumped from the collection trough through meters and 4-inch cement asbestos piping to the individually valved demonstration lakes. Automatic water level recorders are installed in perforated 12-inch PVC pipe mounted adjacent to the sampling wells.

Many construction detail drawings have been prepared and utilized during construction, and the included as-built drawings are intended to show only the salient features of filter construction (Plates 6 & 7).

5.06 PLAN FOR OPERATION

The initial plan for operation of the Pilot Filter Plant utilizing wastewater treatment plant activated sludge effluent consists of:

1. Scheduling Influent Application
   a. Frequency - daily
   b. Volume - approx. 100,000 gallon
   c. Rate - 300,500 g.p.m.
   d. Period - 4-6 hrs. (1000-1600 hrs.)
   e. Application Point - No. 1 Basin, initially
2. Control of Influent Application
   a. Frequency - filter requirement
   b. Volume & Rate - gate valves and meters
   c. Period - Wastewater Treatment Plant production rate and irrigation activity
   d. Phreatic Surface - water level recorders.

3. Filter Effluent
   - a. Collection - continuous
   - b. Pumpage & Rate - automatic and metered, 150 g.p.m. capacity
   - c. Volume - variable
   - d. Application Point - experimental ponds
   - e. Treatment - none
4. Experimental Ponds Operation
   - a. Application Schedule - intermittant and alternate, at rate variable with filter production
   - b. Flow Pattern - south to north in paired ponds
   - c. Discharge - north ponds to drainage ditch
   - d. Stock - Channel cat, Tilapia, or Rainbow Trout (seasonally)
   - e. Management and Control - University of Arizona Cooperative Fisheries Unit

Discussion of Plan of Operations:

The operation that will charge the conditioned filter consists of spreading an activated sludge effluent to the most distal filter basin. This effluent was chosen because of its low BOD, ABS, and SS, and Figure 13 indicates the general quality of the TWTP operation.

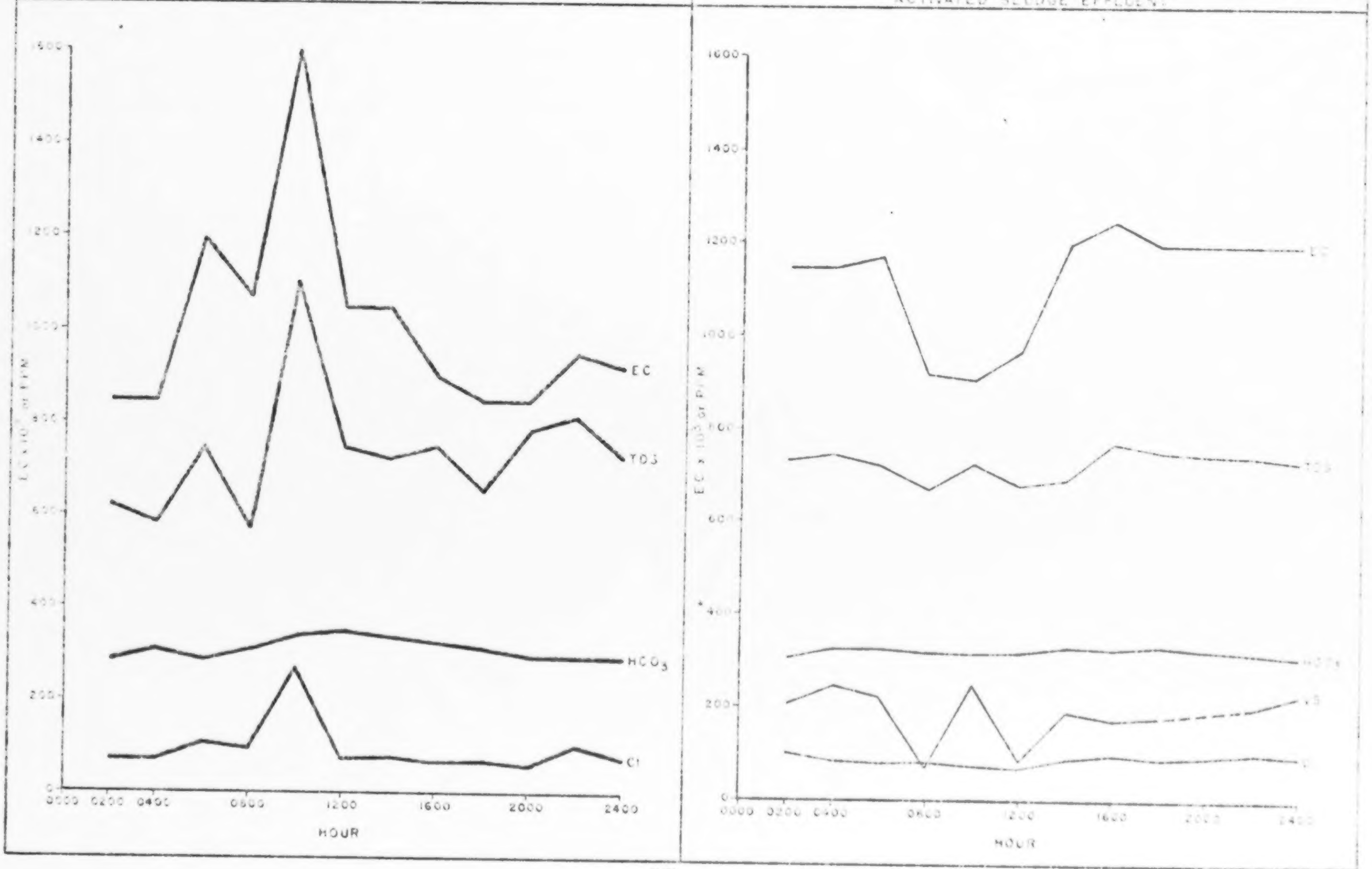
Spreading rate equals approximately 100 M gallons per day over a four to six hour activity period between 1000 and 1600 hours. Application to Basin No. 1 will require the longest travel to reach effluent exit and, therefore, the minimum hydraulic load on the filter.

Flow rates, water levels, and physiochemical characteristics within the filter will be determined during this conditioning period in order to establish the character of that internal activity. The initial

CITY OF TUCSON WATER AND SEWER DEPT. TUCSON WASTEWATER RECLAMATION PROJECT

RESULTS OF 24 HOUR MONITORING OF THE TUCSON SEWAGE TREATMENT PLANT JUNE 20, 1966

FIGURE 13


PLANT INFLUENT

ACTIVATED SLUDGE EFFLUENT

effluent will be delivered to the four unconditioned fish ponds to the east.

5.07 PLAN FOR INVESTIGATION

Analytical evaulation of pilot filter influent, intermediate wells, and effluent sampling points will be carried out in order that filter activity may be monitored.

The conditioning schedule below will be utilized:

Sampling Point	Analysis	Frequency
Influent *	Chem.	2 x daily
	Bact.	2 x weekly
	Vir.	2 x weekly
Intermediary ** (Lines and Pans)	Chem.	On demand
	Bact.	On demand
	Vir.	On demand
Effluent	Chem.	1 x daily
	Bact.	2 x weekly
	Vir.	2 x weekly

NOTE: * Composite for minerological determination.

** Frequency and pattern of sampling is dependent upon filter preconditioning and spreading operations.

During filter conditioning, the influent and effluent will be evaluated as to the N-group (NO_2, NO_3, NH_3, and ORG N), PO_4, and E.C. It was decided in conference to monitor the intermediary well sampling lines for E.C., Alkalinity, D. O., $_pH$, and ORP. (TWRP Form 6-tabulation form).

5.08 GENERAL CONSIDERATIONS

(1) Experimental Fish Ponds - The committee's recommendation on the variety of fish to be eventually utilized within the pond waters; a. Channel Cat, b. Rainbow Trout, c. Tilapia.

(2) Liaison to be established with the University of Arizona Botony Department to study the plankton incident to pilot plant operation.

(3) Further thought will be given to the security and beautification of the filter pilot plant as presented, through liaison with the City of Tucson Parks and Recreation Department.

(4) Review or collect data on N content in effluent irrigation soils within the project area.

(5) The collection time for virological sampling will be coordinated with bacteriology sampling periods.

(6) During preconditioning, spreading bays should be completely inundated.

CHAPTER 6

MICROBIOLOGY AND VIROLOGY

By: Peter P. Ludovici, Ph. D.

6.01 METHODOLOGY

Because of the relative infrequency of virus particles in sewage in comparison with the "indicator" coliform organisms or fecal streptococci, it has been found advisable to resort to a different type of specimen for virus tests. Two techniques have been investigated. The first involved immersing gauze swabs in the infiuent and effluent flow for 2 to 3 days. The second technique required the use of specially constructed small sterile columns packed with gauze through which flow could be controlled at a rate of 1 g.p.m. for 2 or 3 days. Expressed fluid from the gauze constituted the samples for virologic studies.

Initial processing of the sewage samples for virus determinations collected as above indicated consisted of adjustment of the pH to approximately 8.0, with 1 N sodium hydroxide (with phenol red indicator) to minimize viral absorption. The adjustment of pH is accomplished while the swabs are still in the plastic bags. After thorough mixing, the fluid was expressed and transferred to flasks to which normal inactivated chicken serum is added to a final concentration of 2.5%. Specimens were then either stored at -60° C, or one or both of the two differential centrifugations were performed before storage. The first centrifugation was at 6,000 rpm for thirty minutes to remove bacteria and large particles. The supernatant fluid from this centrifugation was centrifuged at 50,000 rpm, or 198,000 X G for two hours to sediment virus. Sterile gelation to a final concentration of 0.06% was added just prior to this centrifugation to enhance adherence of the pellet in the centrifuge tube. The supernatant fluid was decanted and the pellet resuspended in one-tenth of the original volume in tissue culture maintenance medium containing antibiotics. Aliquots were stored at -60° C until appropriate tissue cultures were available for inoculation.

Each concentrated specimen was inoculated routinely into two tubes each of primary African green monkey kidney and primary human amnion tissue cultures.

An abscrption period of two hours at 36° C was allowed each inoculated culture, following which the inoculum was decanted, the cell layer washed once with Hanks' balanced salt solution, and fresh maintenance medium was added. Incubation was at 36° on a revolving tissue culture drum. Cultures were examined microscropically at one or two day intervals for viral cytopathic effect. Those specimens showing no cytopathic effect during a two-week observation period will be given a second serial passage. Positive culture tubes representing the same specimen were treated individually for virus identification, which is accomplished by neutralization test except for adenovirus. The adenovirus group is identified by the complement-fixation test and no attempt was made to determine specific adenovirus type. In many instances, during the process of identification of a virus, a terminal dilution purification titration was performed. The end point of the titration is assumed to be the point where probably only the predominating virus remains. This eliminated mixtures of viruses in cultures, although occasionally it was necessary either to do an additional terminal dilution purification or to separate the different viruses by use of specific antisera incorporated in the passage medium.

Procedures for the preparation of human amnion tissue culture cells have been standardized. Other cell lines including H_eL_a and HE_{p-2} are now being incorporated in our standard assay procedures. Using these cell types, seed stock to several entroviruses have been prepared.

In addition, procedures are being stabilized in the laboratory to subsequently handle effluent water samples when the stabilization ponds are constructed. These procedures include the training of laboratory workers in the detection of "unknown" pathogenic enteric bacteria and viruses.

Infectious hepatitis virus is presumed to be present in sewage, as a number of water-borne outbreaks of viral hepatitis have been traced by epidemiological methods. However, no accepted technique for the cultivation of these viruses has yet appeared. It is our intention to test out culture methods advocated by various investigators and to search for other tissue lines that might be useful in the culture of the hepatitis agent.

The techniques used in this work are essentially those developed for the Santee Water Reclamation Project and thus, permit a qualitative detection of viruses contaminating water. We are now prepared to test water specimens before and after filtration through the recently completed earth filter using such qualitative procedures. Based on Santee's experience, however, the effluent from such a filtration process probably will not contain detectable viruses. For this reason, we are investigating some of the recently reported techniques for concentrating and detecting subinfectious quantities of virus from natural fluids. One of these, a multiple millipore filtration technique developed by Wallis and Melnick (1966) appears to be promising. In this method, large quantities of water under pressure are passed through a sequential series of filters in order to (1) clarify the water (fiberglass prefilter), (2) remove bacteria, yeasts, and molds (0.22 mu filter), (3) treat water with magnesium chloride and protamine sulfate,

(4) remove protein precipitated material (fiberglass filter), and (5) concentrate the viruses by absorption onto the filter pad (0.45 mu filter).

Subsequently the viruses are released from the filter pores by grinding the membrane with sand and foetal calf serum in a mortar. The resulting fluid is inoculated into bottles containing cell monolayers followed by the use of an agar overlay. Thus viruses can be detected and individually isolated by the plaques they form to provide a quantitative procedure for detecting subinfectious quantities of virus in water samples. This system has recently been incorporated into the study.

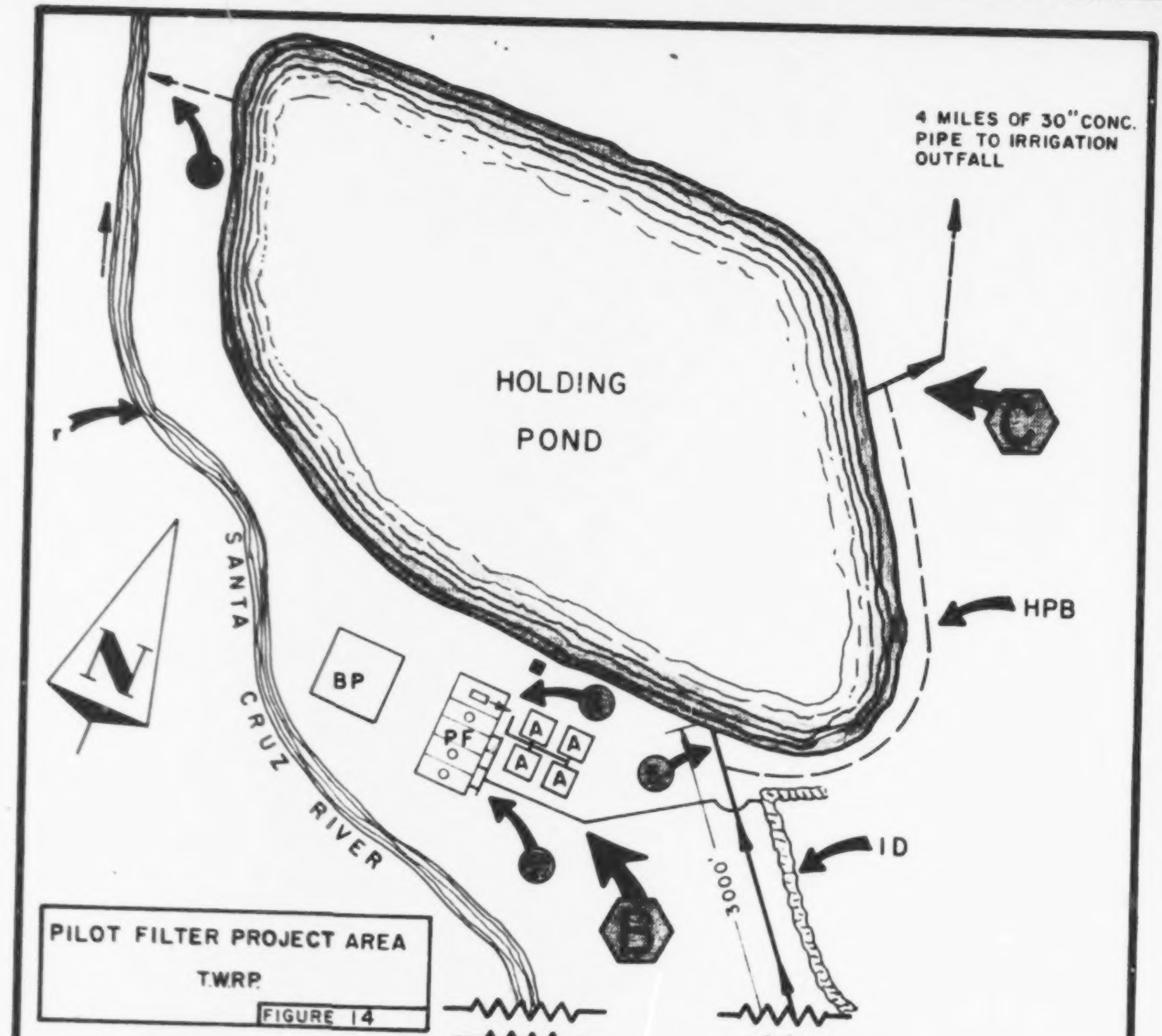
6.02 RESULTS:

Initial phases of the project have now been completed. These include preliminary studies on the viral and bacteriological flora of the Tucson Wastewater Treatment Plant effluents and wells within the project area.

Viral studies included:

1. Standardization of virus isolation methods;
2. Preparation, standardization, and testing of antisera pools in neutralization tests with known stock viruses;
3. Initial sampling of raw sewage, trickling filter, and activated sludge effluents for isolation of viruses; and
4. Initial identification studies on such virus isolates.

To date we have isolated 22 agents from 10 Tucson Wastewater Treatment Plant samples. The sampling points are shown on Figure 14 and described in the legend. Three (3) SPI samples yielded six (6) isolates, one (1) identified as Polio 2, and the remaining five (5) as Echo 12. Two (2) TFE samples yielded six (6) isolates identified as two (2) Echo 12 viruses, and four (4) preliminarily identified as adenoviruses. Three (3) ASE samples yielded nine (9) isolates--seven (7) Echo 12 and two (2) Echo 13.


4 MILES OF 30" CONC. PIPE TO IRRIGATION OUTFALL
HOLDING POND
HPB
SANTA CRUZ RIVER
N
BP
PF
A
A
A
A
ID
3000'
r
FINAL EFFLUENT
LEGEND
① = SEWAGE PLANT INFLUENT (SPI)
② = ACTIVATED SLUDGE EFFLUENT (ASE)
③ = TRICKLING FILTER EFFLUENT (TFE)
④ = SEWAGE PLANT EFFLUENT (SPE) r
⑤ = HOLDING POND INFLUENT (HPI)
⑥ = HOLDING POND EFFLUENT (HPE) r
⑦ = PILOT FILTER INFLUENT (PFI)
⑧ = PILOT FILTER EFFLUENT (PFE)
A = FISH POND
⬢ = PILOT FILTER AREA
BP = BORROW PIT
r = RIVER
FE = FINAL EFFLUENT
ID = IRRIGATION DITCH WITH ASE
PF = PILOT FILTER
⬢ = TUCSON WASTEWATER TREATMENT PLANT
⬢ = OSHRIN IRRIGATION LINE (OIL)
HPB = HOLDING POND BY PASS

PILOT FILTER PROJECT AREA

T.W.R.P.

FIGURE 14

One (1) HPI sample yielded one (1) isolate, not yet identified. One (1) HPEr sample (grab sample) yielded no isolates.

Bacteriological studies included:

1. Standardization of the methods for bacterial analysis of water using the classical procedures.
2. Initial sampling of raw sewage (SPI), trickling filter effluent (TFE), activated sludge effluent (ASE), and sewage plant effluent (SPEr) is presently being carried out by the above procedures.
3. Standardization of methods for the detection of Salmonella-Shigella on selective differential media is also being carried out.

As a result of the Multiple-Millipore technique, future samplings will be on a one to five gallon "grab-sample" basis, thereby obviating the 48 to 72 hour collection period utilized in the swab-gauze pad technique. The same sample will also provide enough material for the bacteriological determinations.

Currently, weekly samplings are being taken from these previously mentioned six (6) points within the Tucson Wastewater Treatment Plant and systematic sampling of the Pilot Filter will soon be initiated.

APPENDIX A

SAMPLE PROJECT FORMS
(In Pocket)

Number

1. Well Data Accumulation Forms (1A and 1B)
2. Water Analyses of Well Data (Form 5)
3. Water Analyses of Sampling Lines Data (Form 6)
4. Soil Analysis Form (S-1)
5. Grain Size Distribution Form (S-2)
6. Filter Media Permeability Sample Identification (S-3)
7. Filter Media Control Record (S-4)
8. Sampling Line Installation & Testing Record (S-5)
9. Well Evaluation Form (D-1)

[illegible]

TUCSON WASTEWATER RECLAMATION STUDY

WATER SAMPLE ANALYSES FOR PROJECT WELL No. ______ | DEPTH______

LOCATION (-) ______ USE ______ STATIC WATER LEVEL______

① Lab Sample No								
② Date Sampled								
③ Temperature °C								
④ Color								
⑤ Turbidity								
⑥ pH								
⑦ ORP								
⑧ EC × 10^3								
⑨ TR or (TSS)								
⑩ FS								
⑪ VS								

		mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
CATIONS	Ca																
	Mg																
	Na																
	NH_4																
	Totals																
ANIONS	F																
	Cl																
	CO_3																
	HCO_3																
	SO_4																
	NO_2																
	NO_3																
	PO_4																
	Totals																

[illegible]										
ABS										
Hardness										
CCE										
BACTERIOLOGY	SPC	2 ml								
		35 ml								
	MF 100 ml	Coliform								
		Fecal Coli								
		Fecal Strep								
	MPN 100 ml	Coliform								
		Fecal Strep								

VIROLOGY:

Remarks:

TUCSON WASTEWATER RECLAMATION STUDY

WATER SAMPLE ANALYSES FOR FILTER SAMPLING LINE

Lab. Sample No.								
Date Sampled								
Temperature°C								
Color								
Turbidity								
pH								
ORP								
$EC \times 10^3$								
TR								
FS								
VS								
SS								

		mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l	mg/l	me/l
CATIONS	Ca																
	Mg																
	Na																
	NH_4																
	Totals																
ANIONS	F																
	Cl																
	CO_3																
	HCO_3																
	SO_4																
	NO_2																
	NO_3																
	PO_4																
	Totals																

Closure										
ABS										
Hardness										
Org.-N										
COD										
BOD										
DO										
CCE										
BACTERIOLOGY	SPC	20°/ml								
		35°/ml								
	MF 100 ml	Coliform								
		Fecal Colif.								
		Fecal Strep.								
	MPN/100	Coliform								
		Fecal Strep.								

VIROLOGY:

Remarks:

TWRS Form 6 4/1965 Revised 5/1966, 8/1966

TUCSON WASTEWATER RECLAMATION STUDY

WPD 108-01-65

			WELL 1		WELL 2		WELL 3		WELL 4S		WELL 4N	
			S	L	S	L	S	L	S	L	S	L
DEPTH TO SAMPLING LINE	18 FEET	E										
		W										
	15 FEET	E										
		W										
	12 FEET	E										
		W										
	9 FEET	E										
		P										
		W										
	6 FEET	E										
		P										
		W										
	3' FEET	E										
		P										
		W										

T.W.R.S FORM S-5 4/66

WPD 108-01-65

WELL ______________________ RATING ______________________

A) Rating for project well selection

1) Accessibility ______________________

2) Facility of sampling ______________________

3) Sampling point ______________________

4) Facility of flaming ______________________

5) Flushing facility ______________________

6) If sampled from pressure tank, rating of sample freshness __________

7) Well subject to pumping periods ______________

8) Special conditions ______________________

B) Topographical notes

1) Proximity to effluent irrigated areas ______________

2) Proximity to river ______________________

C) Sanitary Conditions:

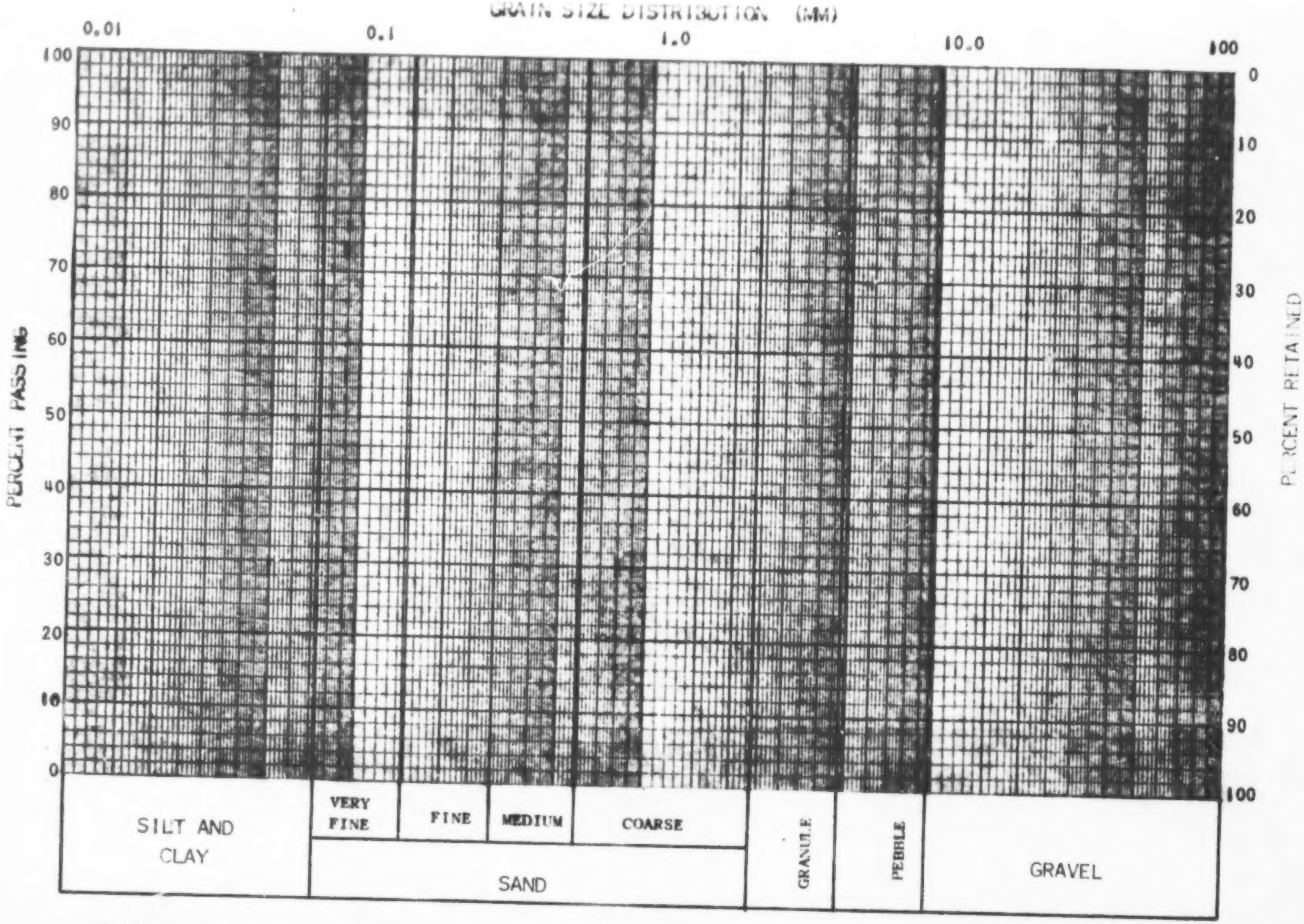
D) Description of local:

TWRS-D-1

WPD 108-01-65

TUCSON WASTEWATER RECLAMATION STUDY

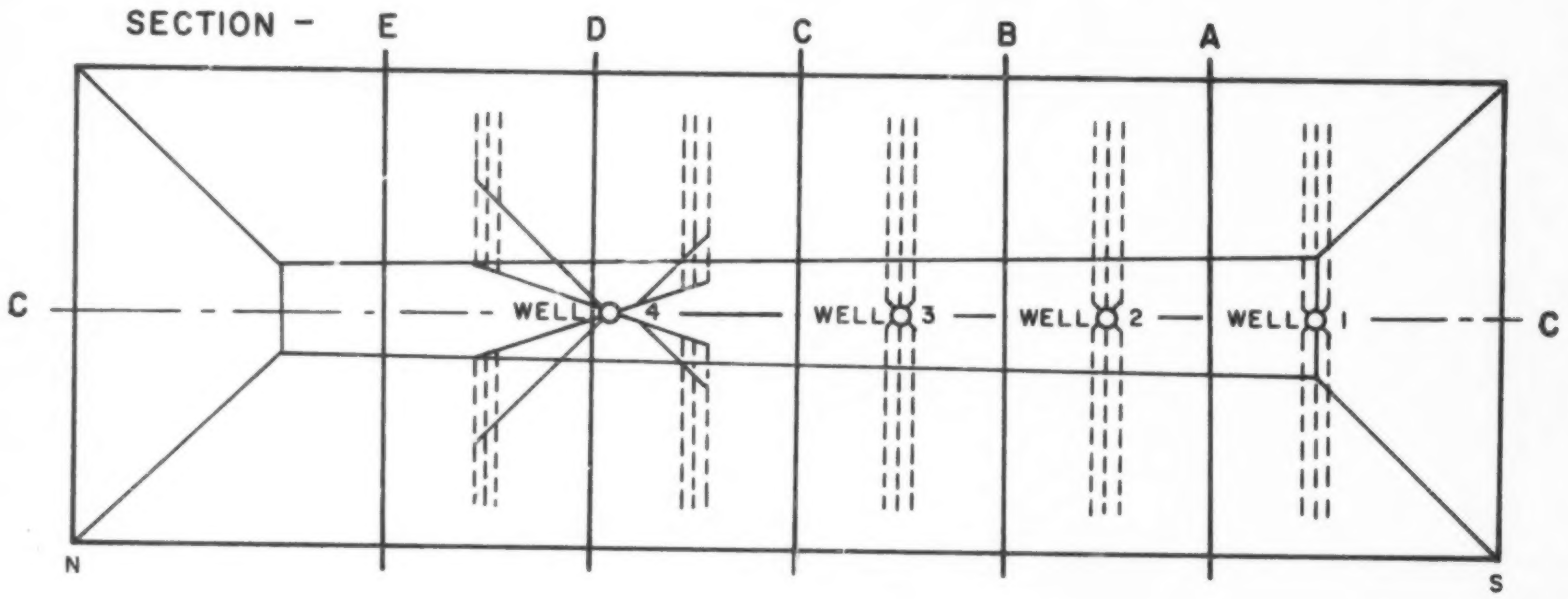
SAMPLE NO____ LOCATION__________ DATE ANALIZED_______

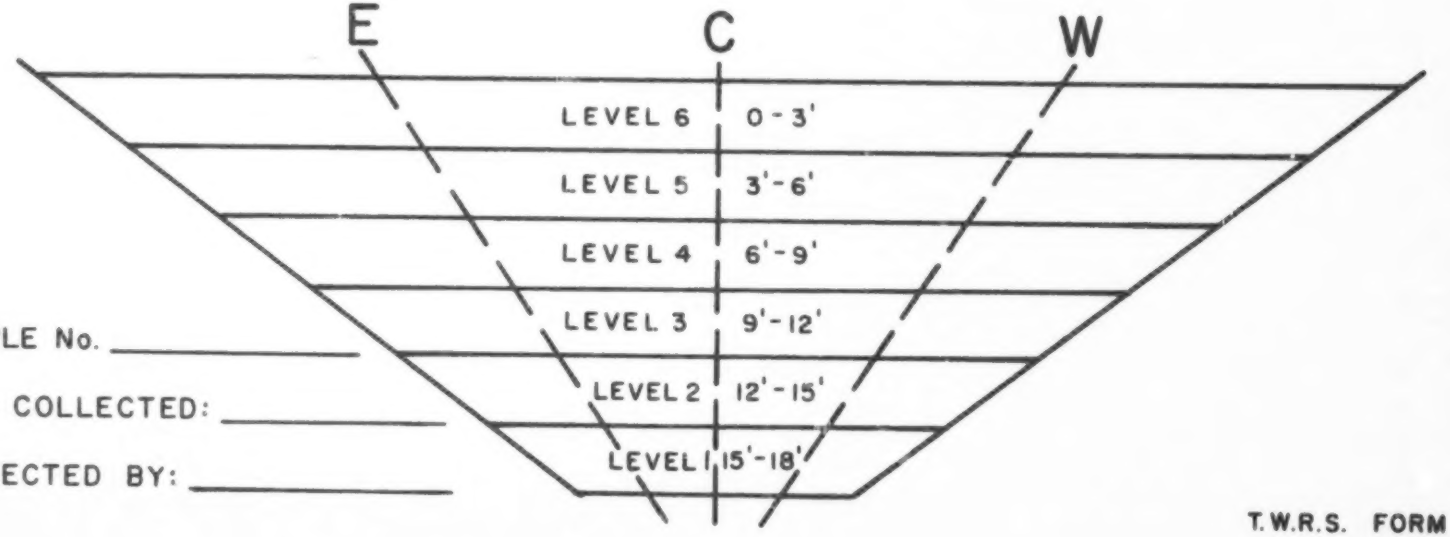


T.W.R.S. Form S-2 10/1965

WPD 108-01-65

TUCSON WASTEWATER RECLAMATION STUDY


SECTION -
E
D
C
B
A
C
WELL 4
WELL 3
WELL 2
WELL 1
C
N
S


E
C
W
LEVEL 6
0-3'
LEVEL 5
3'-6'
LEVEL 4
6'-9'
LEVEL 3
9'-12'
LEVEL 2
12'-15'
LEVEL 1
15'-18'

SAMPLE No. ______________

DATE COLLECTED: ______________

COLLECTED BY: ______________

T.W.R.S. FORM S-3
4/1966

WRD 108.01-65

TUCSON WASTEWATER RECLAMATION STUDY

SECTION

			A		B		C		D		E	
			MA	P	MA	P	MA	P	MA	P	MA	P
DEPTH	LEVEL 1 15'-18'	E										
		C										
		W										
	LEVEL 2 12'-15'	E										
		C										
		W										
	LEVEL 3 9'-12'	E										
		C										
		W										
	LEVEL 4 6'-9'	E										
		C										
		W										
	LEVEL 5 3'-6'	E										
		C										
		W										
	LEVEL 6 0-3'	E										
		C										
		W										

T.W.R.S FORM S-4 4/66

TUCSON WASTEWATER RECLAMATION STUDY SOIL ANALYSIS

WPD 108-01-65

SAMPLE NO. ____________

DATE COLLECTED ____________

LOCATION ______________________________

DATE ANALYZED ____________

WEIGHT SAMPLE (WET) + PAN ________ GMS: (DRY) ________ GMS

WEIGHT PAN ________ GMS: ________ GMS

WEIGHT SAMPLE (WET) ________ GMS: (DRY) ________ GMS

MOISTURE CONTENT = $\frac{\text{WT. WET \_\_\_\_\_\_ - WT. DRY \_\_\_\_\_\_}}{\text{WT. DRY. \_\_\_\_\_\_}}$ X 100 = ________ %

MATERIAL	SIEVE		WT. SAMPLE & SIEVE(DRY) (GMS)	WT. SIEVE (GMS)	SAMPLE WT. (GMS)	INDIV. % RETAINED	CUMMULATIVE % PASSING TO BE PLOTTED
	NO.	MM					
GRAVEL	3/8"	9.42		596.6		%	%
PEBBLE	4	4.70		585.9		%	%
GRANULES	8	2.36		454.8		%	%
COARSE SAND	30	.59		432.3		%	%
MEDIUM SAND	50	.30		441.9		%	%
FINE SAND	100	.149		374.2		%	%
VERY FINE SAND	200	.074		397.7		%	%
SILT & CLAY *	PAN			381.1		%	%

TOTALS ________ GMS. ________ GMS. ________ GMS. ________ %

* For Washed Samples:

TOTAL SAMPLE WEIGHT (DRY) ________ GMS.

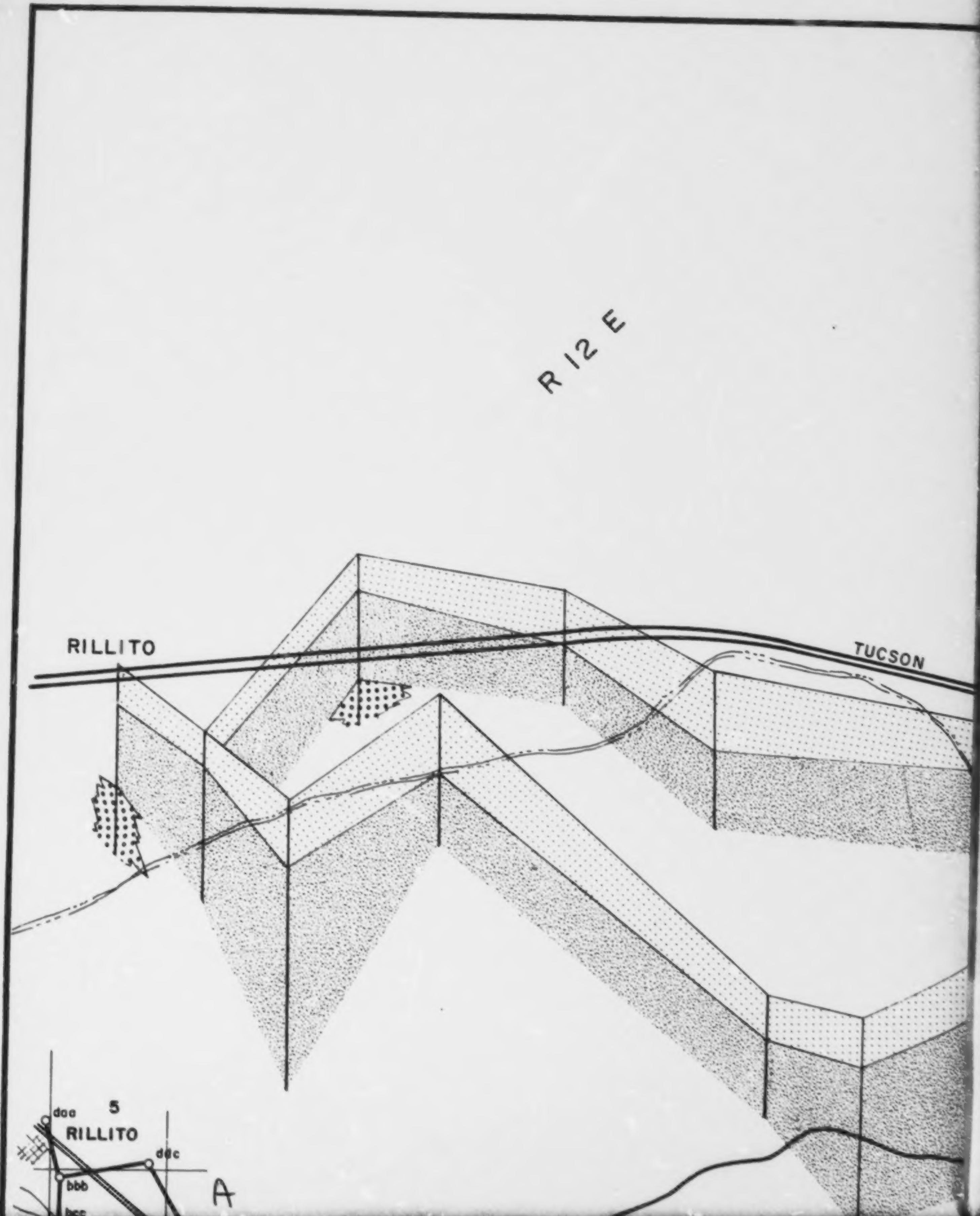
TOTAL WASHED SAMPLE (DRY) ________ GMS.

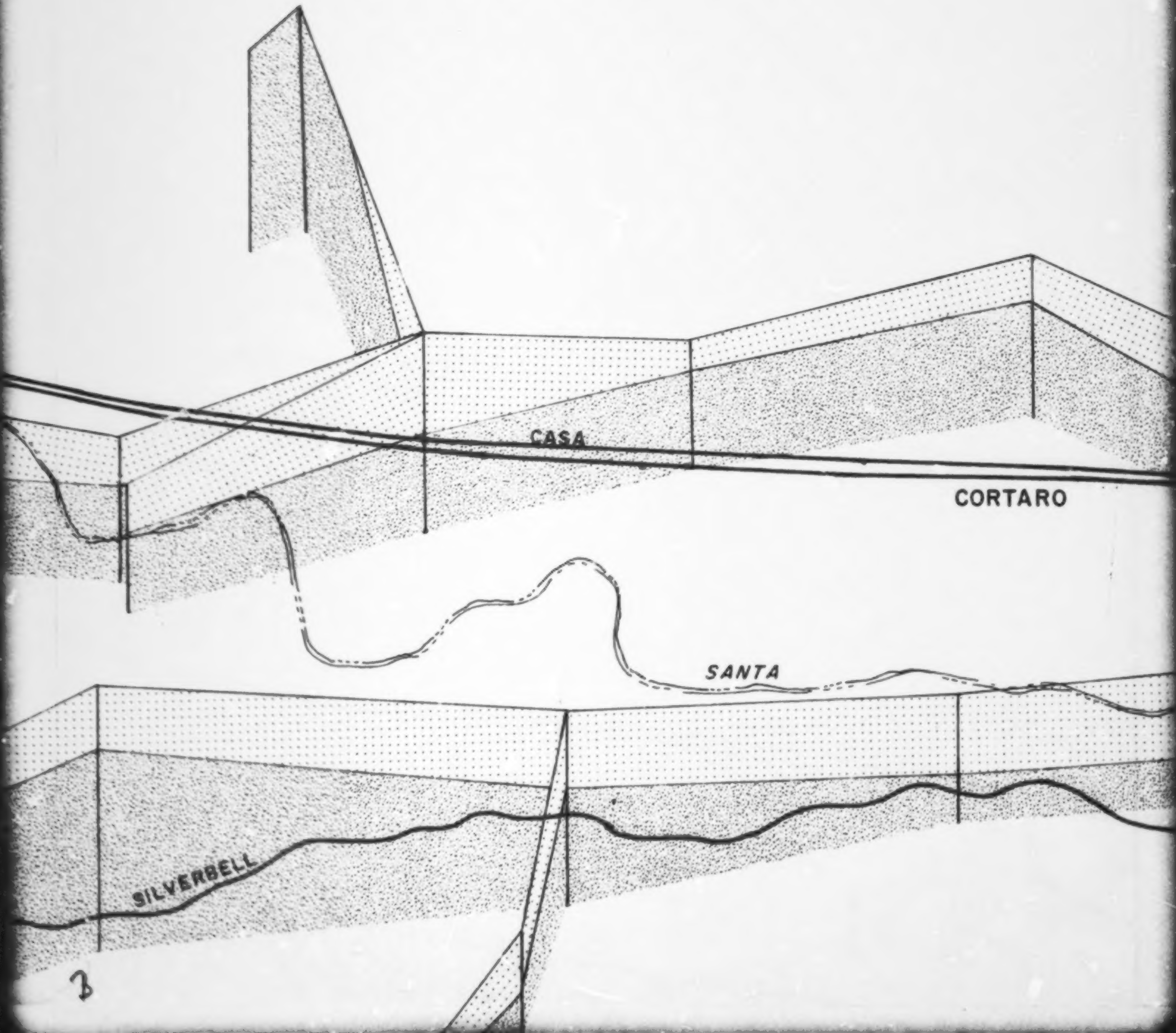
SILT AND CLAY ________ GMS. ________ % ________ %

REMARKS:

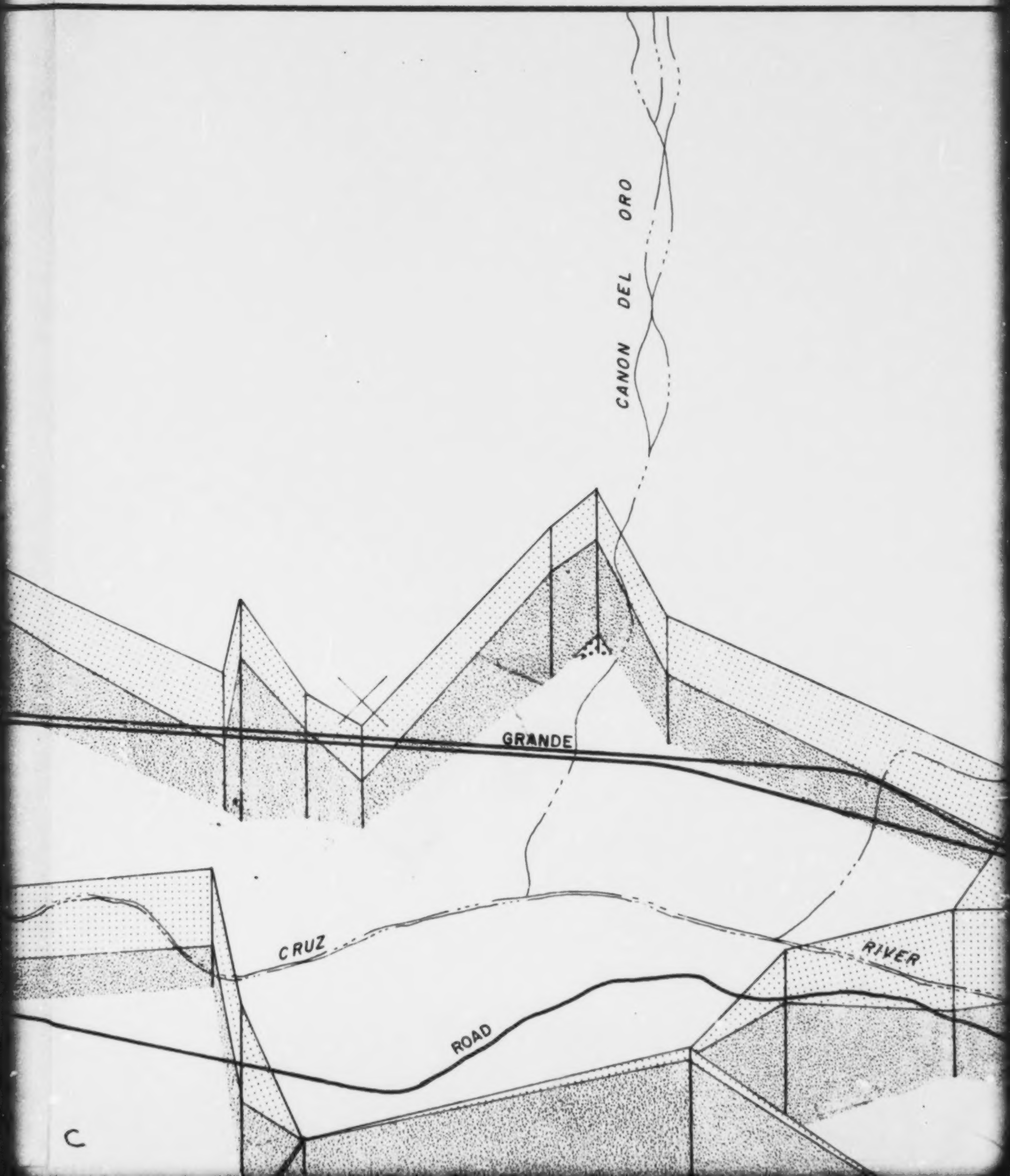
____
ANALYZER

Revised 3/1966
T.W.R.S. Form S-1 10/1965

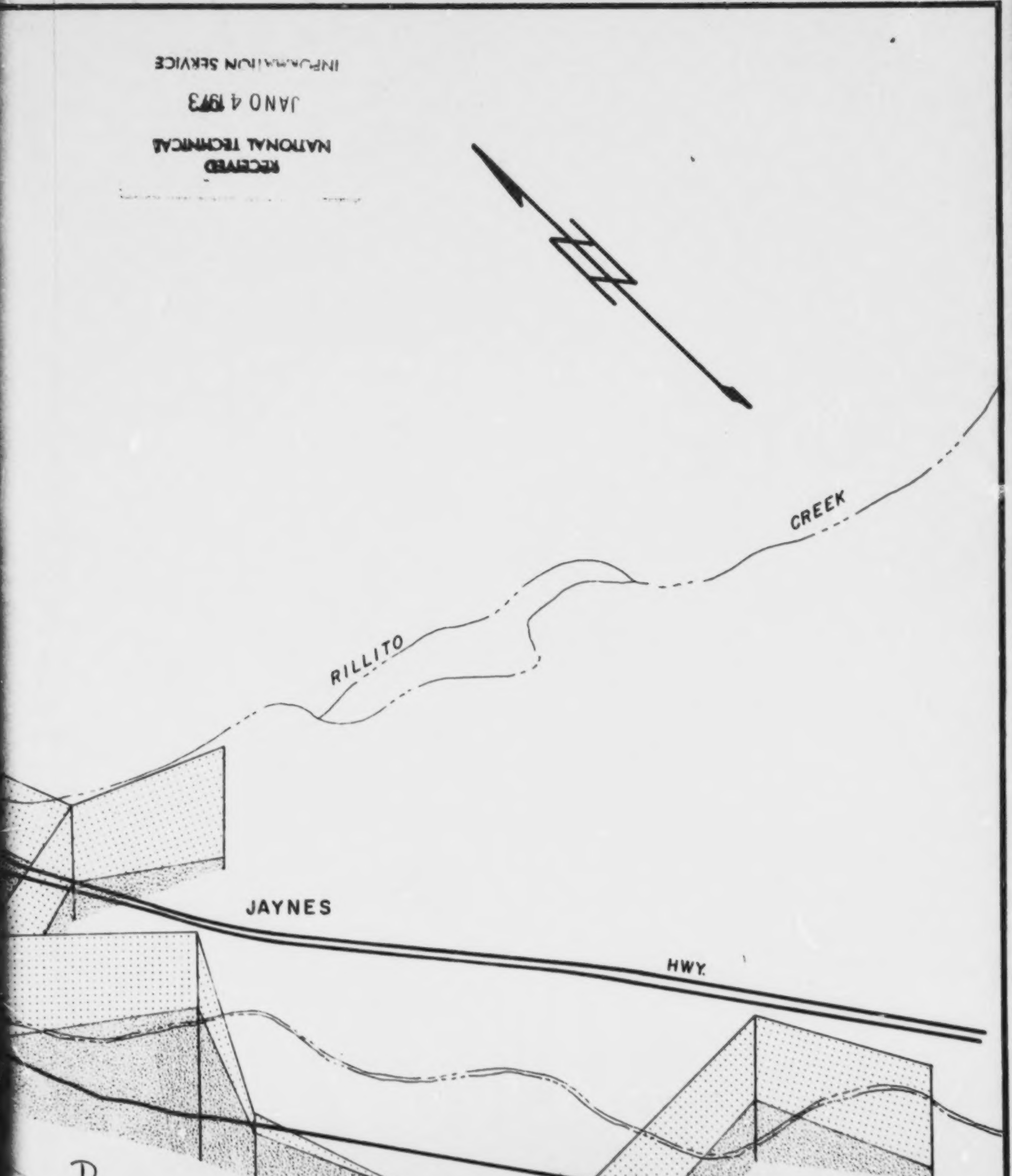

R 12 E
RILLITO
TUCSON
5
daa
RILLITO
ddc
bbb
bcc
A

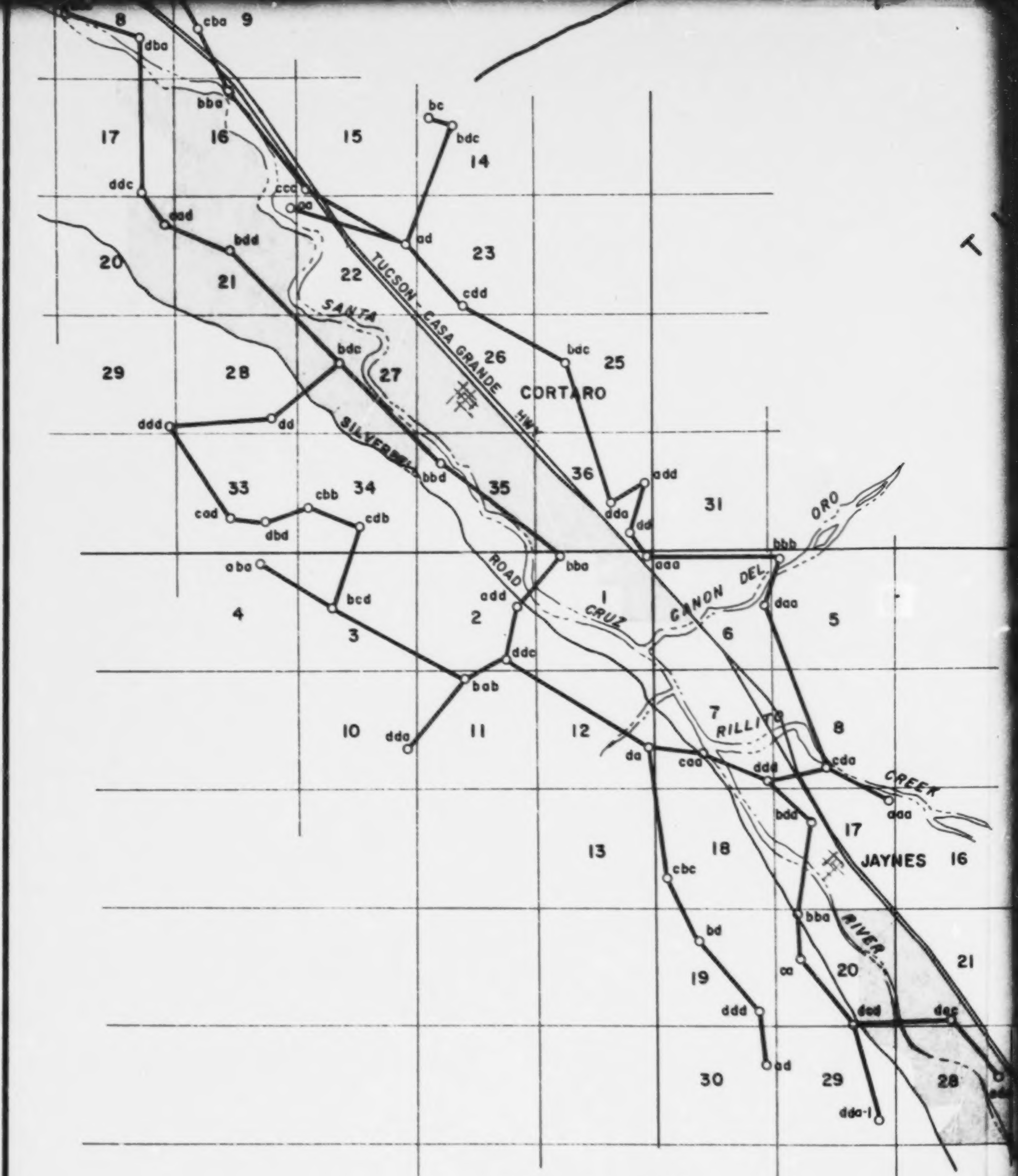

CASA
CORTARO
SANTA
SILVERBELL

3


CANON DEL ORO
GRANDE
CRUZ
RIVER
ROAD
C

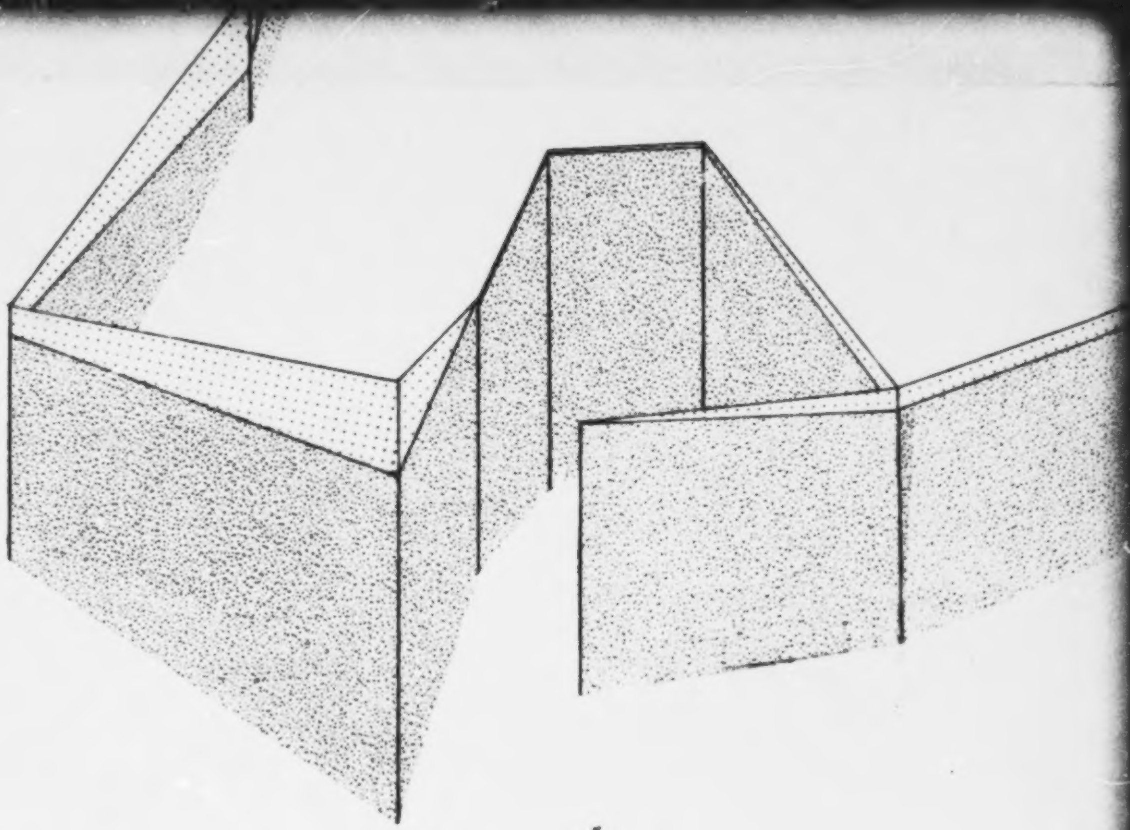
RECEIVED
NATIONAL TECHNICAL
JAN 0 4 1973
INFORMATION SERVICE


RILLITO
CREEK
JAYNES
HWY.
D


8
cba
9
dba
bba
17
16
15
bc
bdc
14
ddc
ccc
aa
aad
bdd
ad
23
20
21
22
TUCSON - CASA GRANDE HWY.
cdd
SANTA
bdc
26
25
29
28
27
CORTARO
ddd
dd
SILVERBELL
bbd
35
36
add
33
34
cbb
cad
dbd
cdb
dda
dd
31
ORO
bbb
aba
bba
aaa
ROAD
CRUZ
CANON DEL
4
bcd
add
1
daa
5
3
2
6
ddc
bab
7
10
dda
11
12
RILLITO
8
da
cad
ddd
cda
CREEK
aaa
bdd
17
13
18
cbc
JAYNES
16
bba
RIVER
bd
19
aa
20
21
ddd
dad
dac
ad
30
29
28
dda-1

INDEX MAP

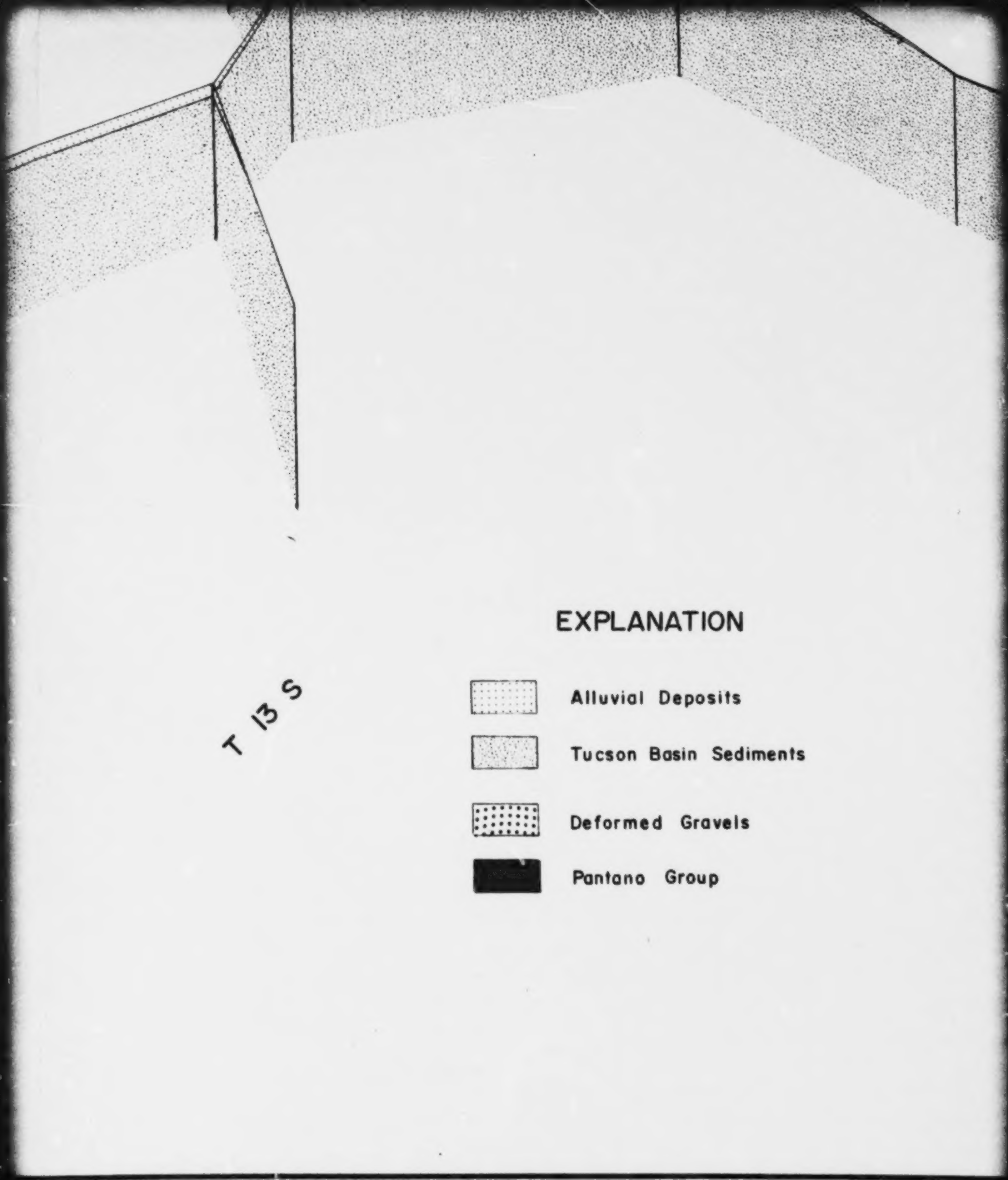
E



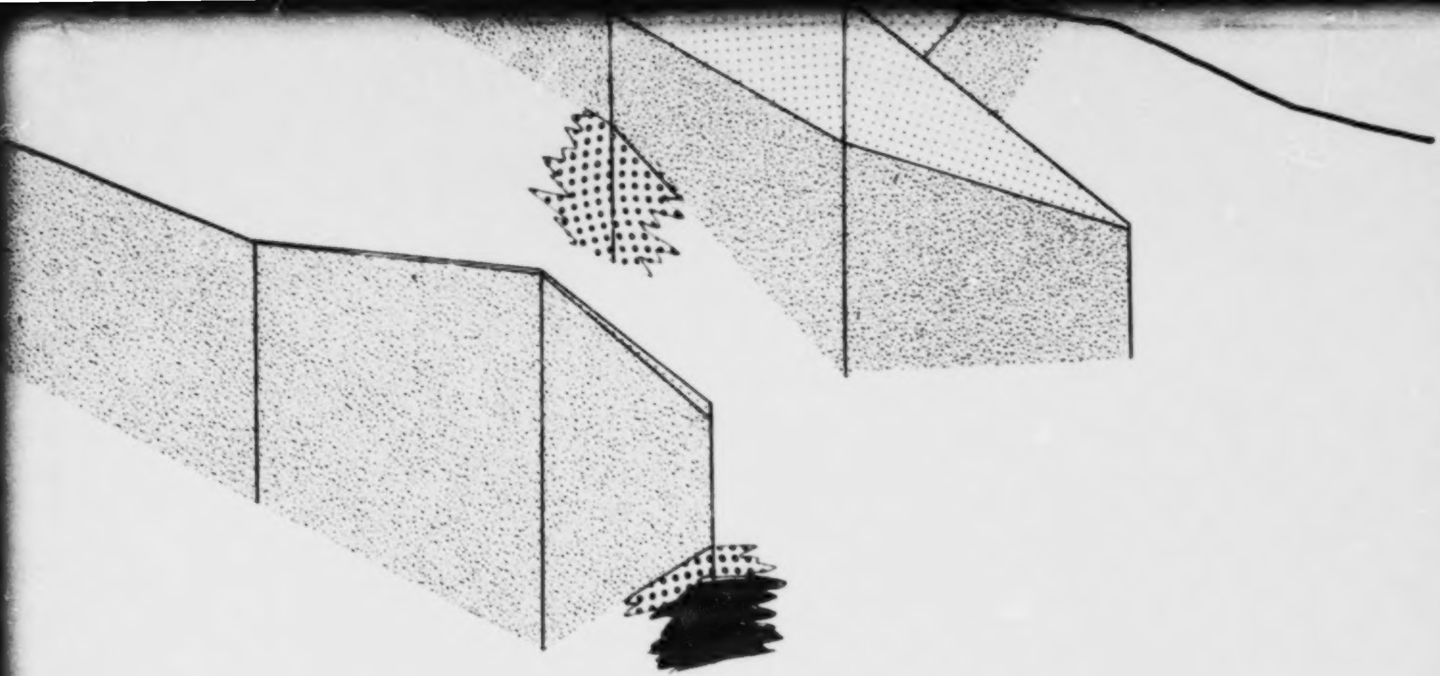
NOTES:

1) HORIZONTAL SCALE: 1" = 2.6 Mi. (approx.)
VERTICAL SCALE 1" = 200'

2) SHADED AREA ON INDEX MAP IS EFFLUENT IRRIGATED


T 13 S
EXPLANATION
Alluvial Deposits
Tucson Basin Sediments
Deformed Gravels
Pantano Group

G



WPD 108-01-65

CITY OF TUCSON WATER DEPT.

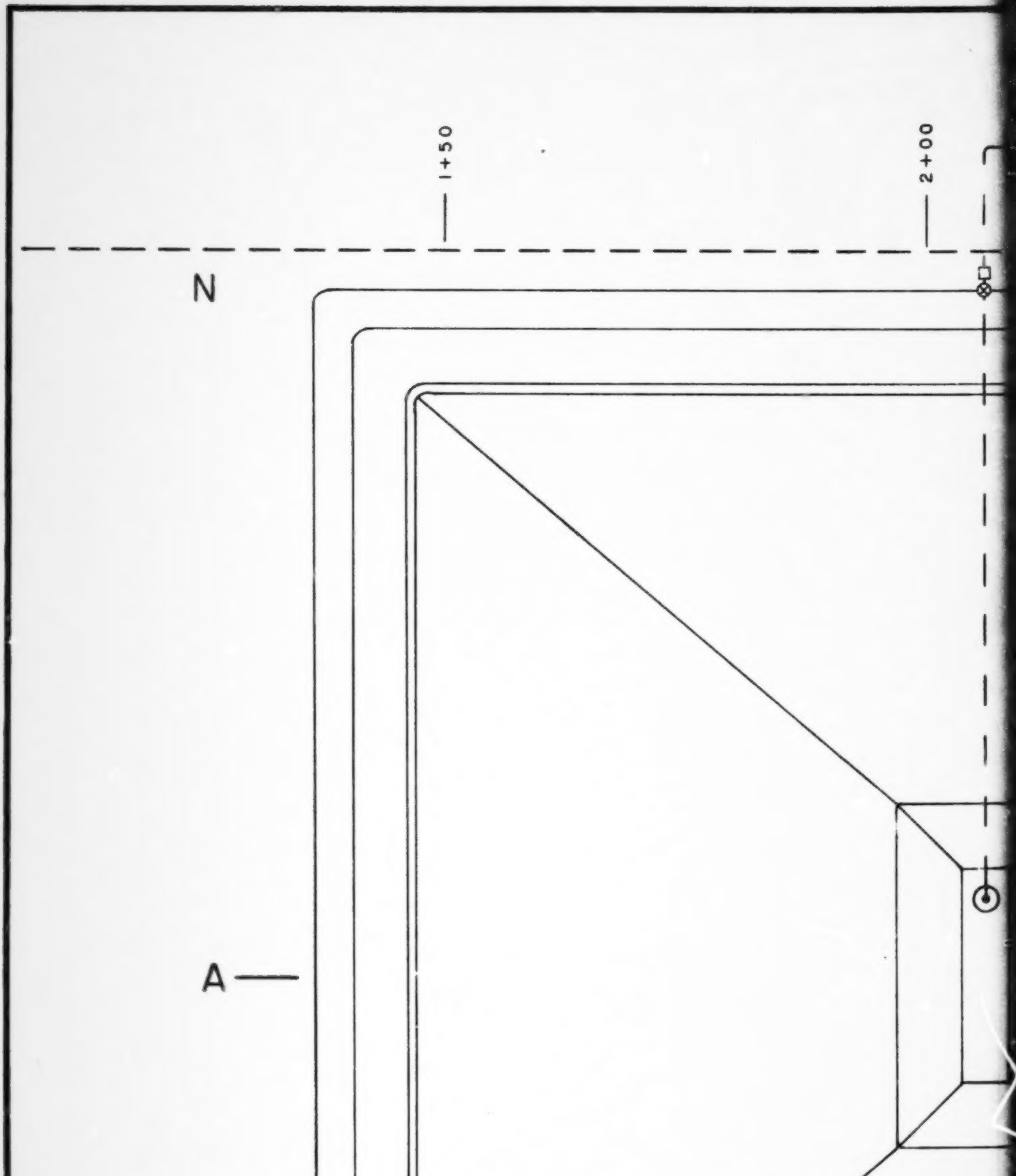
PLANNING & RESEARCH SECTION

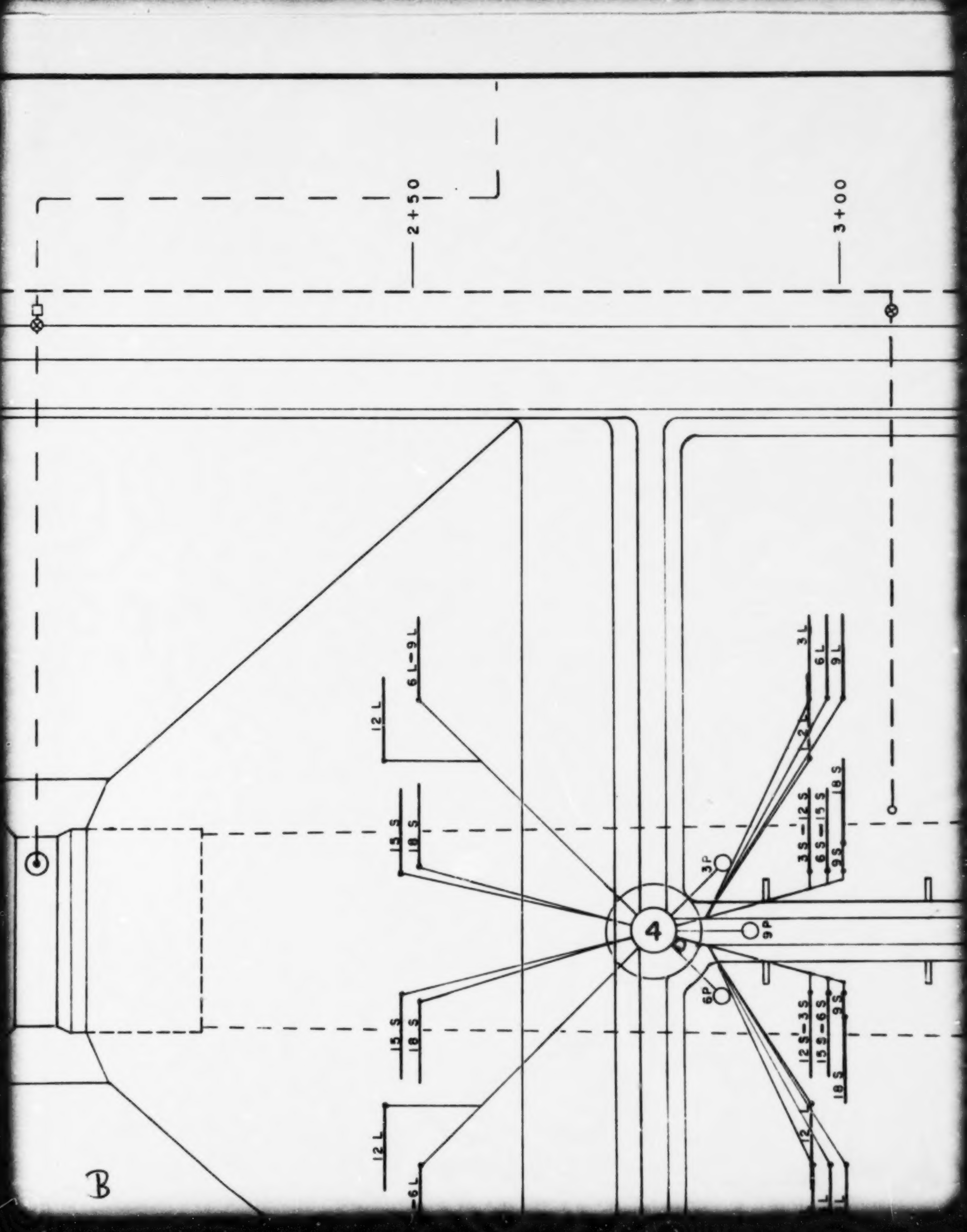
TUCSON WASTEWATER RECLAMATION STUDY

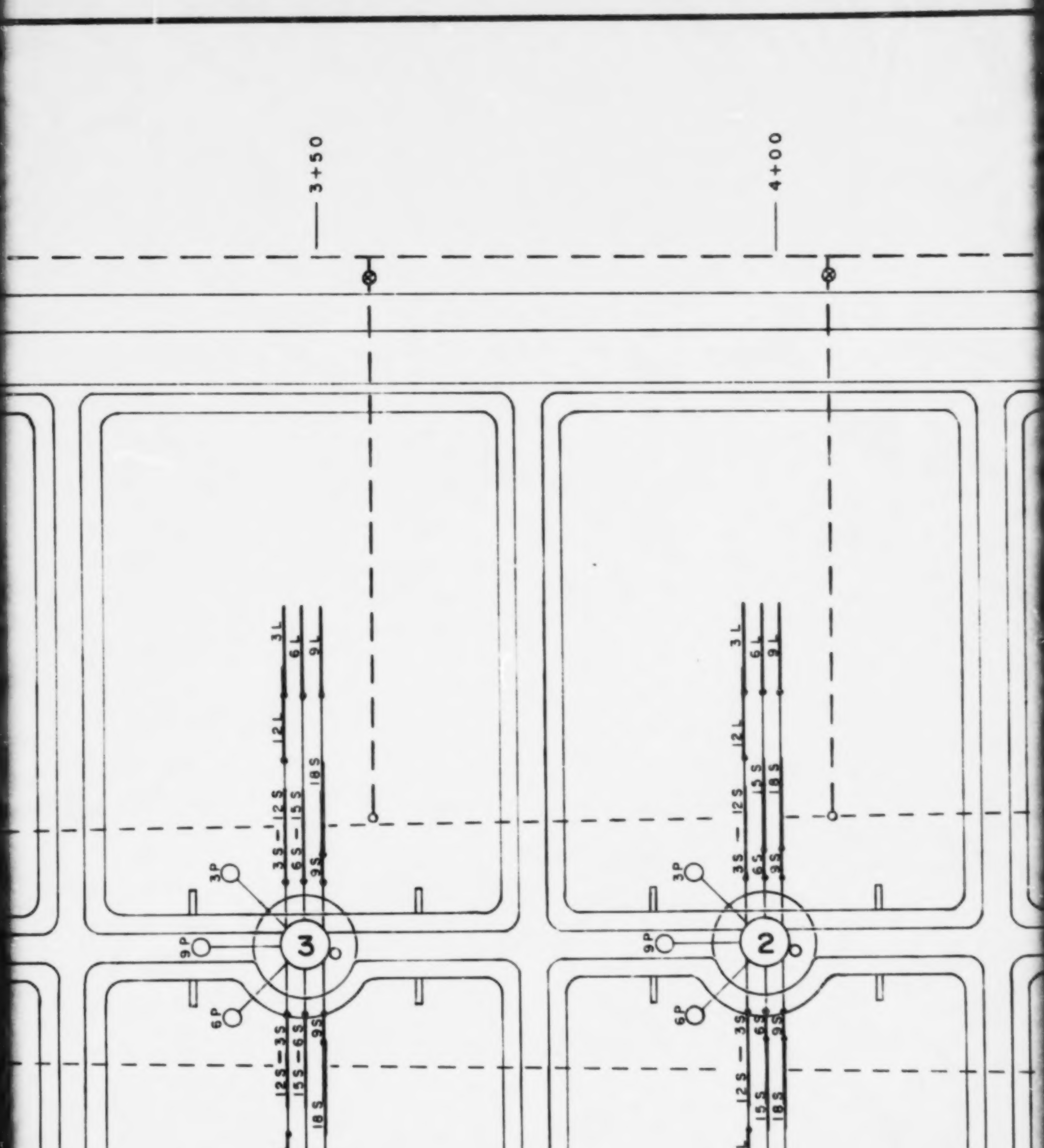
FENCE DIAGRAM

DATE: OCT. 7, 1965	DRAWN BY: E. FERNANDEZ	PLAN NO. PLATE NO. 5
SCALE: SEE NOTE	GEOLOGY BY: G. LAMMERS	

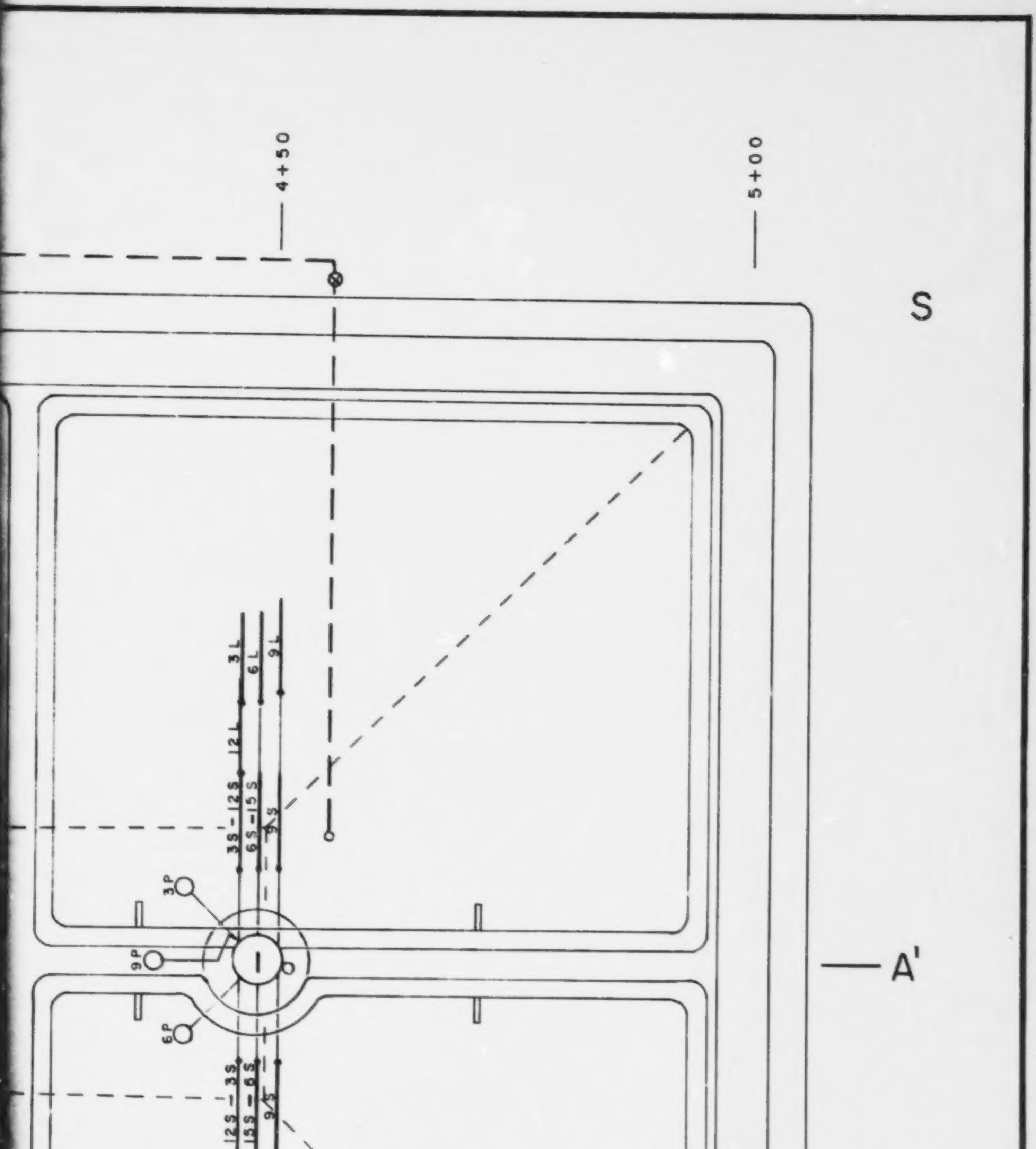
H


1+50
2+00
N
A
A

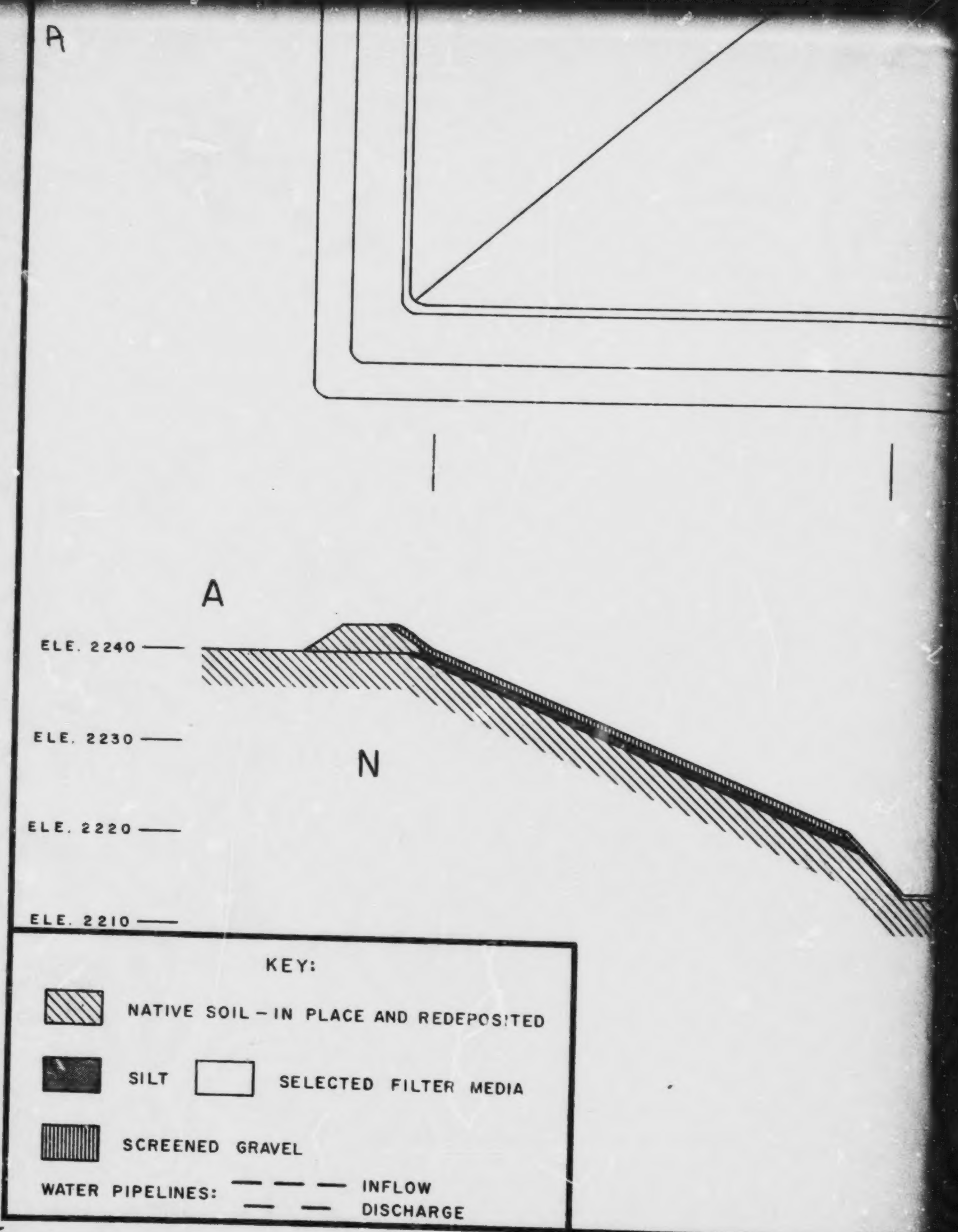

2+50
3+00
12 L
6 L–9 L
15 S
18 S
3 L
6 L
9 L
2 L
18 S
3 S–12 S
6 S–15 S
9 S
3P
9P
6P
4
15 S
18 S
12 S–3 S
15 S–6 S
9 S
18 S
12
12 L
6 L
B



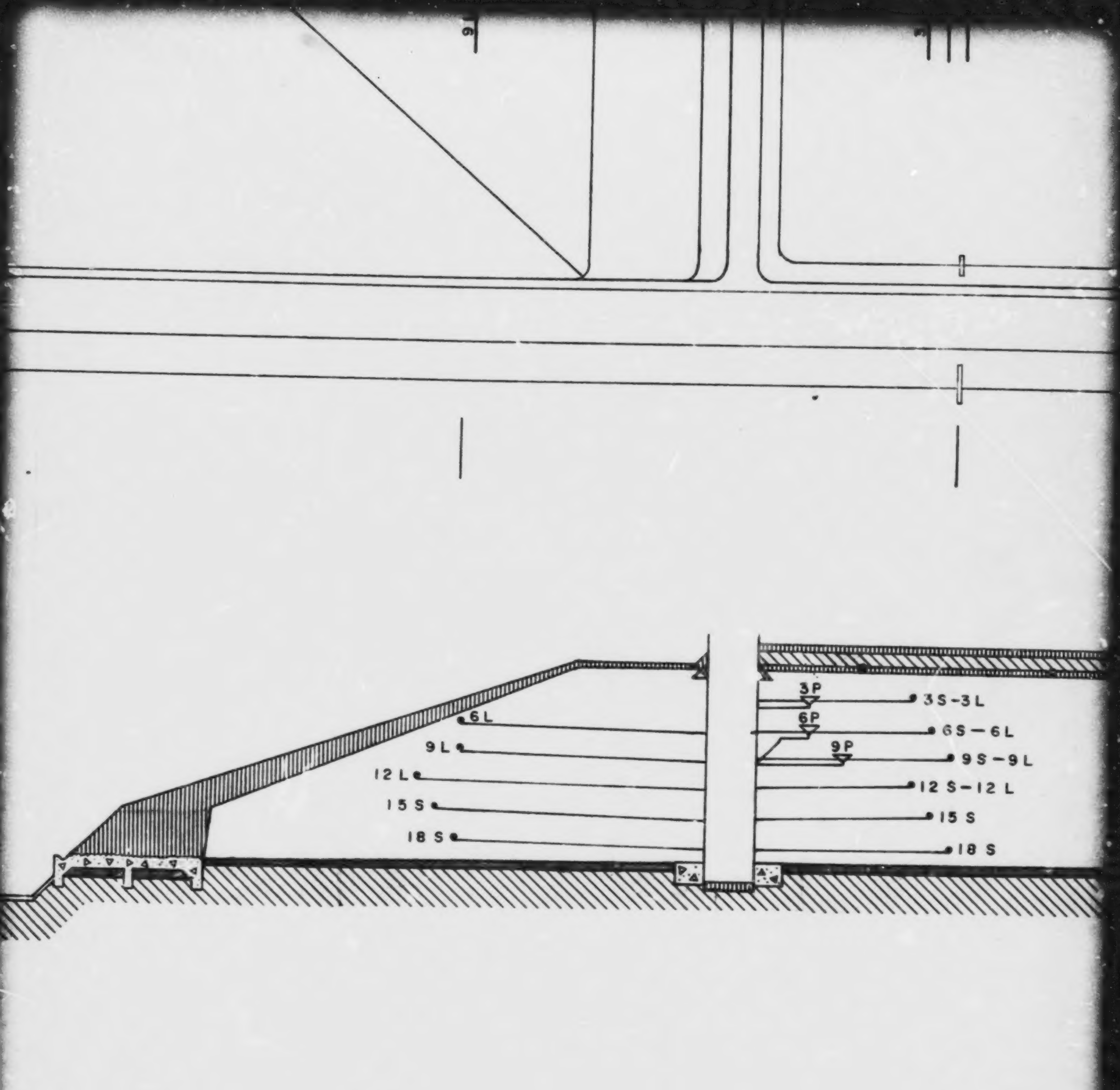
3+50
4+00
3
2
3P
9P
6P
3L
6L
9L
12L
3S - 12S
6S - 15S
9S
18S
15S
12S - 3S
15S - 6S
3S
6S
12S
C

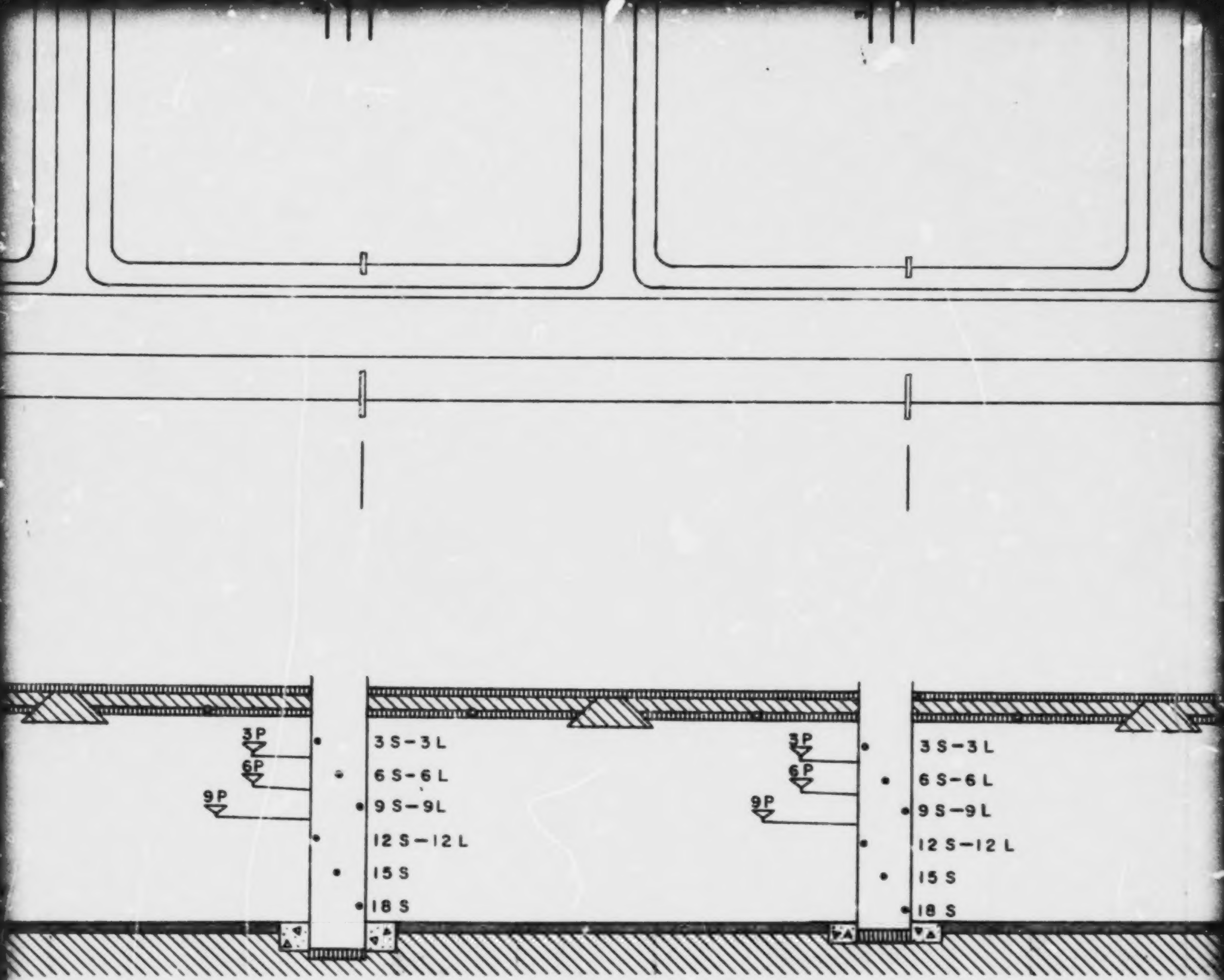

4+50
5+00
S
A'
3L
6L
9L
12L
3S-12S
6S-15S
9S
3P
9P
1
6P
12S-3S
15S-6S
9S
12L

A

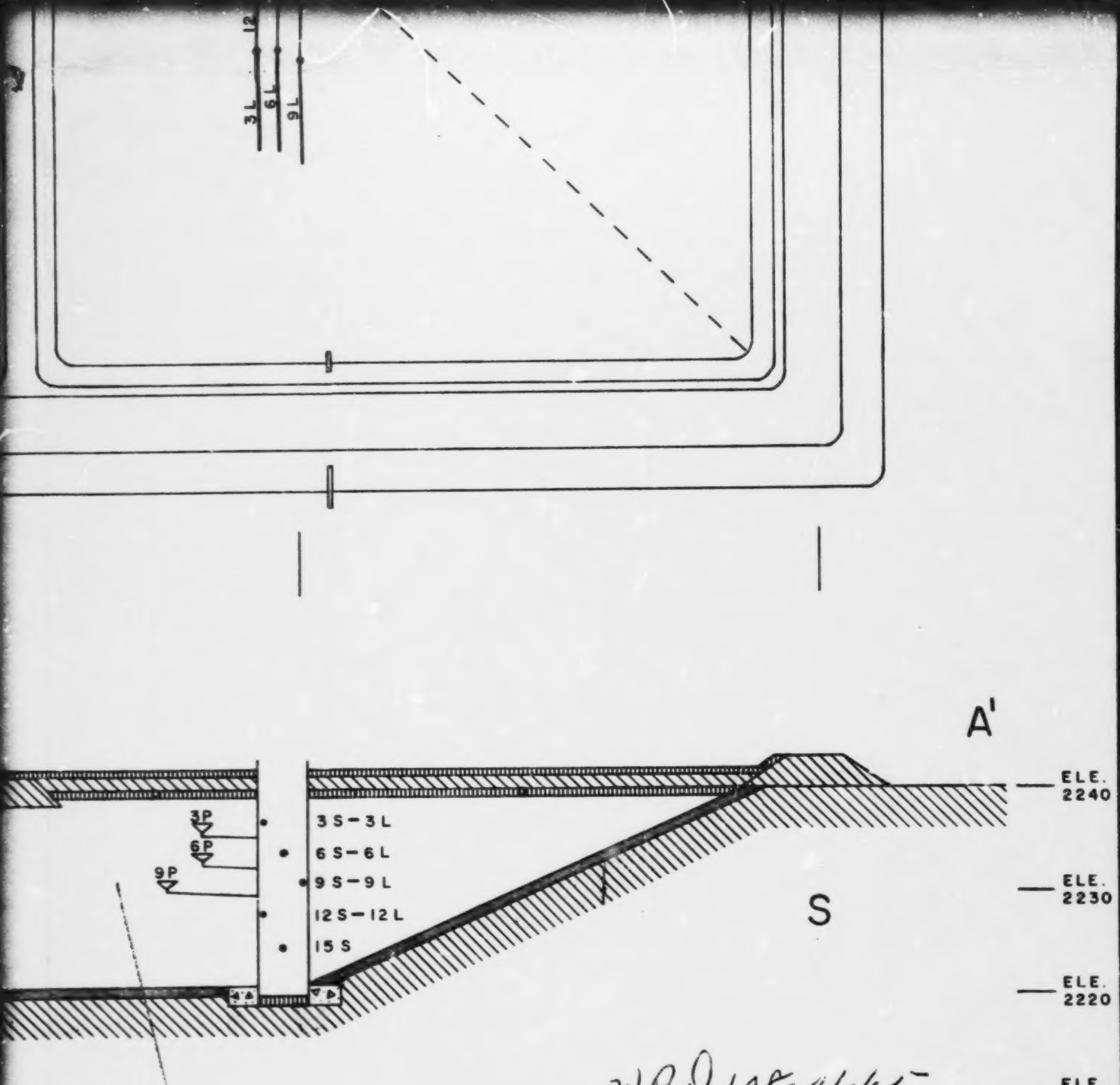

A
ELE. 2240
ELE. 2230
N
ELE. 2220
ELE. 2210
KEY:
NATIVE SOIL - IN PLACE AND REDEPOSITED
SILT
SELECTED FILTER MEDIA
SCREENED GRAVEL
WATER PIPELINES:
INFLOW
DISCHARGE

E


3P
6P
9P
6L
9L
12L
15 S
18 S
3S-3L
6S-6L
9S-9L
12 S-12 L
15 S
18 S


3P
6P
9P
3S-3L
6S-6L
9S-9L
12S-12L
15S
18S
3P
6P
9P
3S-3L
6S-6L
9S-9L
12S-12L
15S
18S

G


12
3L
6L
9L
A'
ELE. 2240
3P
6P
9P
3S-3L
6S-6L
9S-9L
12S-12L
15S
S
ELE. 2230
ELE. 2220
ELE. 2210

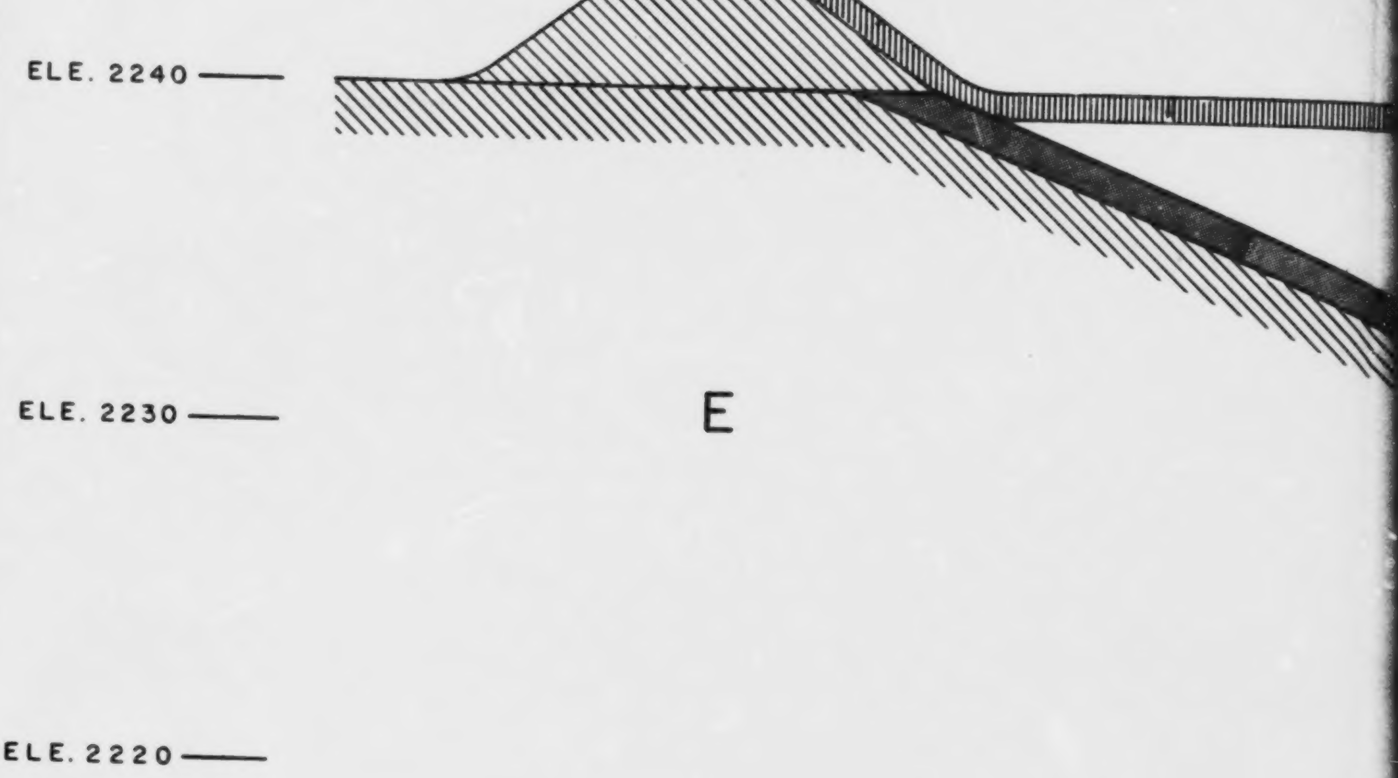
WPD108-01-65

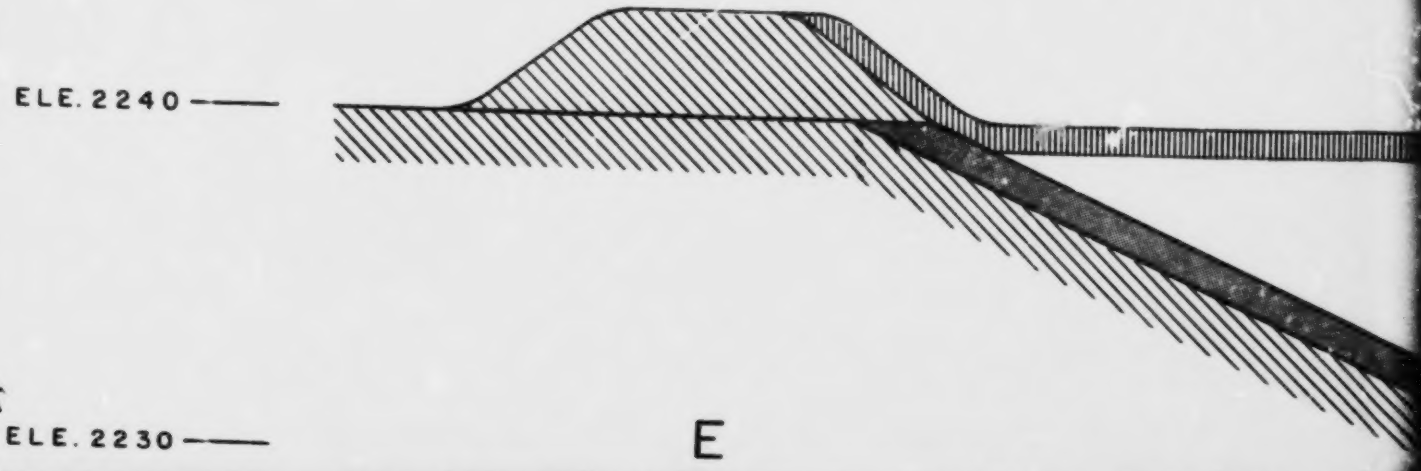
CITY OF TUCSON WATER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

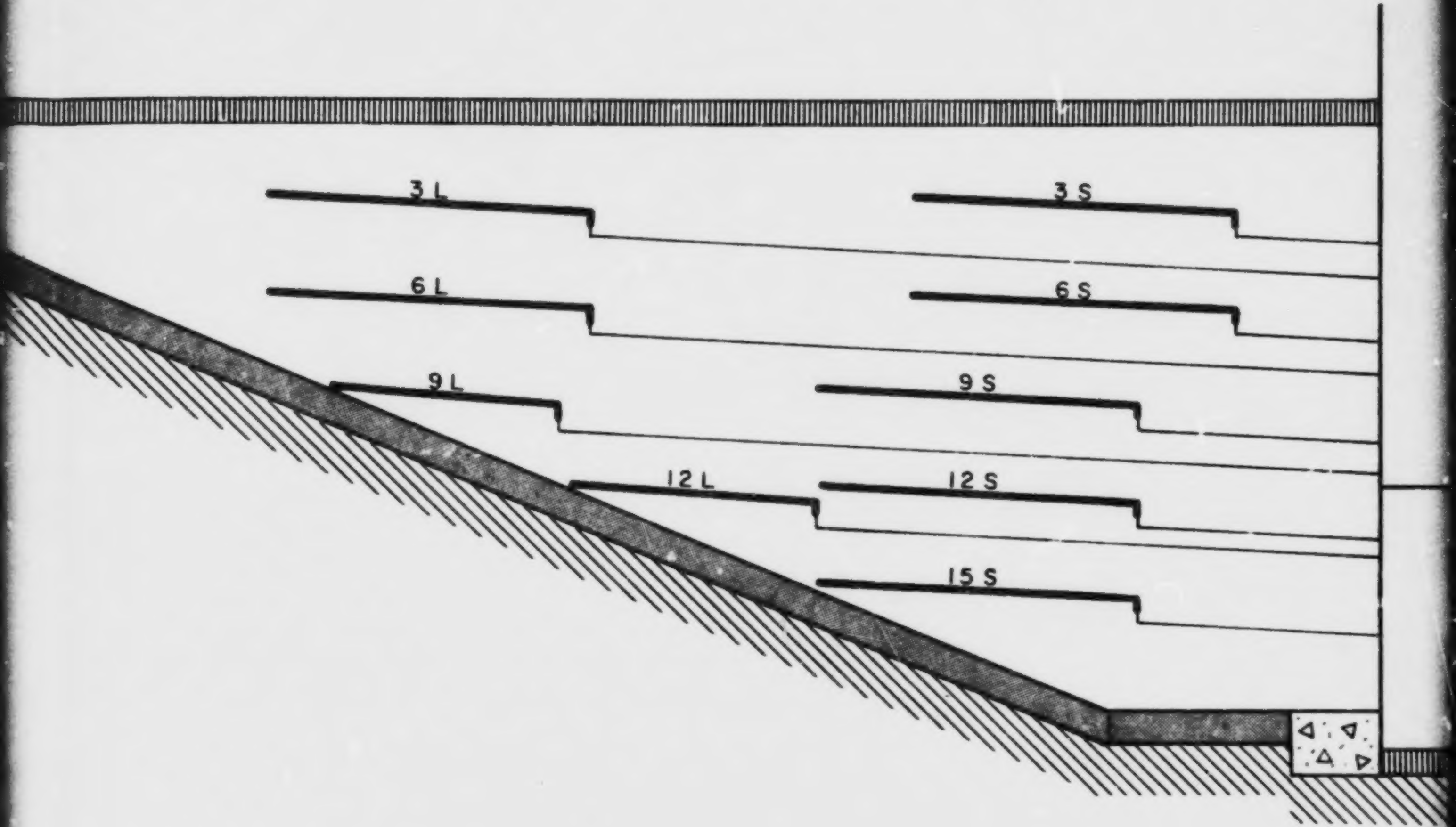
PILOT FILTER – AS BUILTS
PLAN AND ELEVATION A-A'

DATE: JULY 1966	DRAWN BY W.T.S.	PLAN NO. **PLATE NO. 6**
VERT. and HORIZ. SCALE: 4" = 50'	CHECKED BY G. D.	SHEET OF

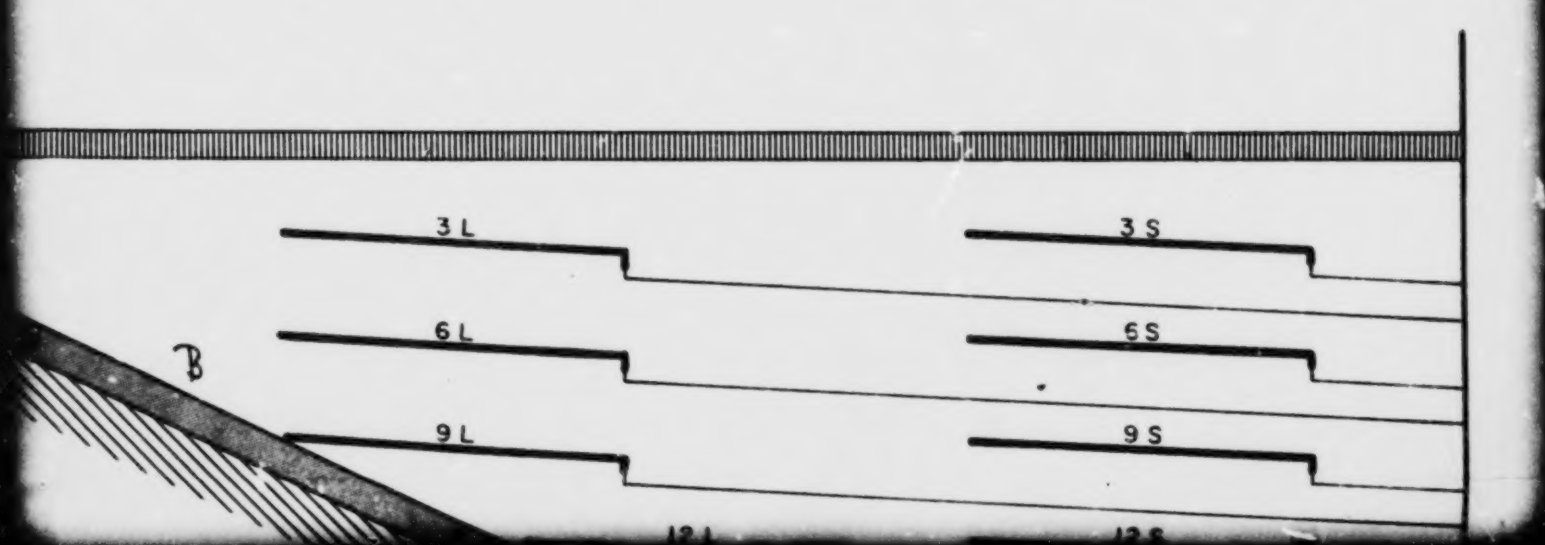

ELE. 2240
ELE. 2230
E
ELE. 2220

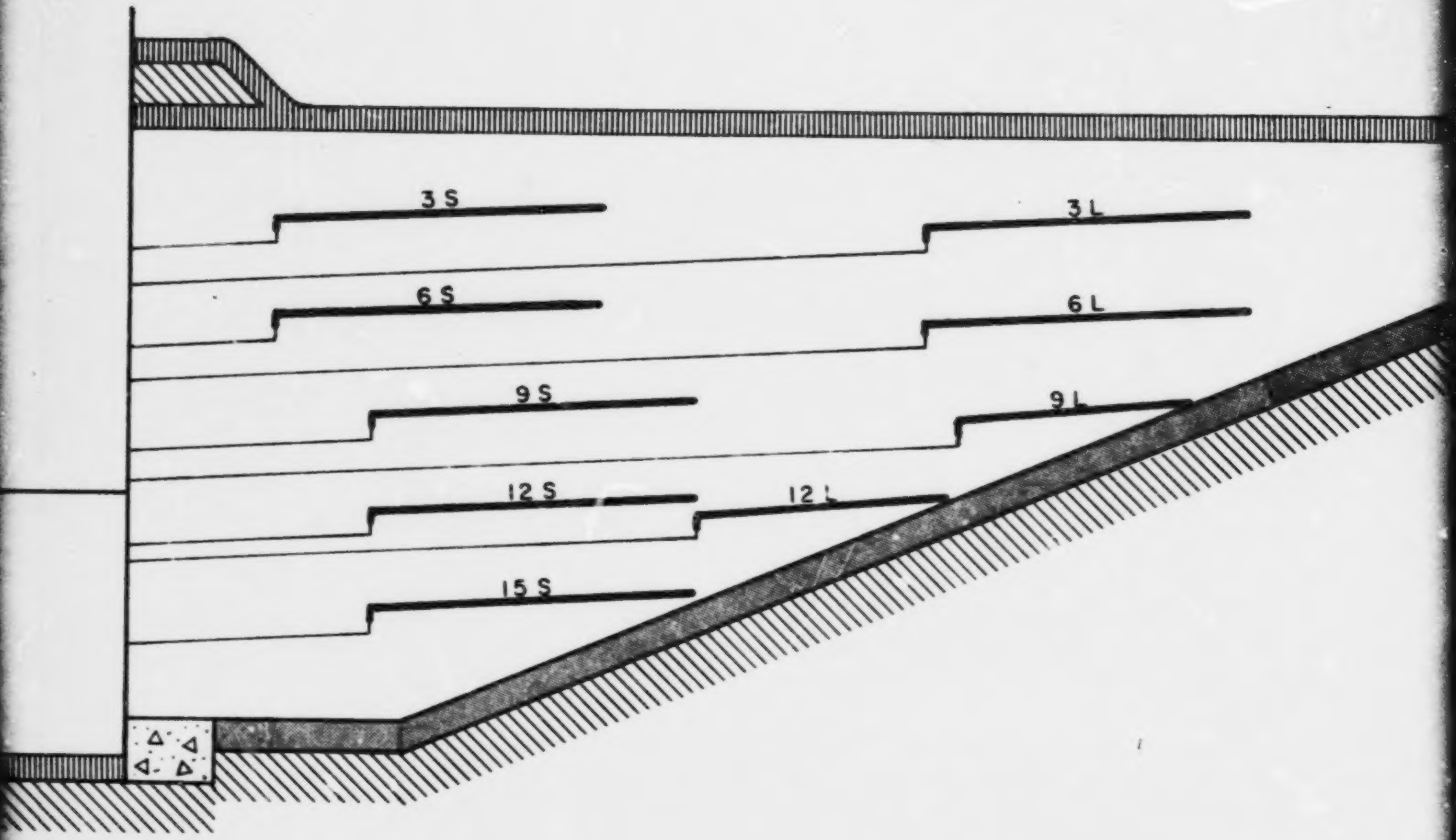

ELE. 2240
ELE. 2230
E

A

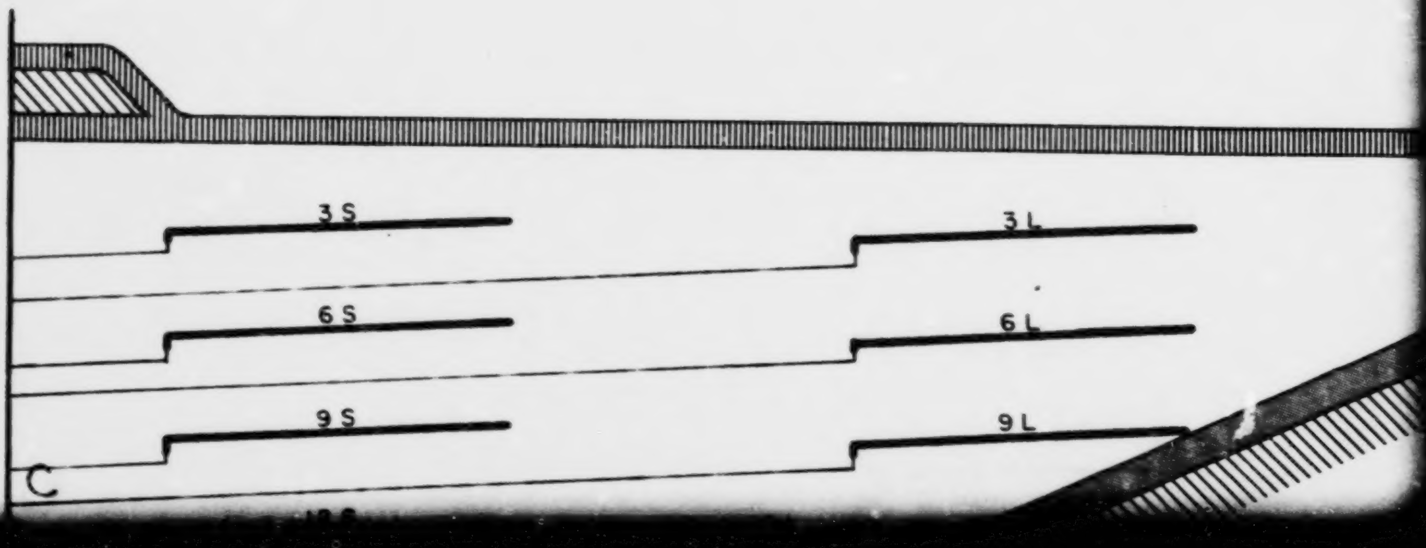

3 L
3 S
6 L
6 S
9 L
9 S
12 L
12 S
15 S

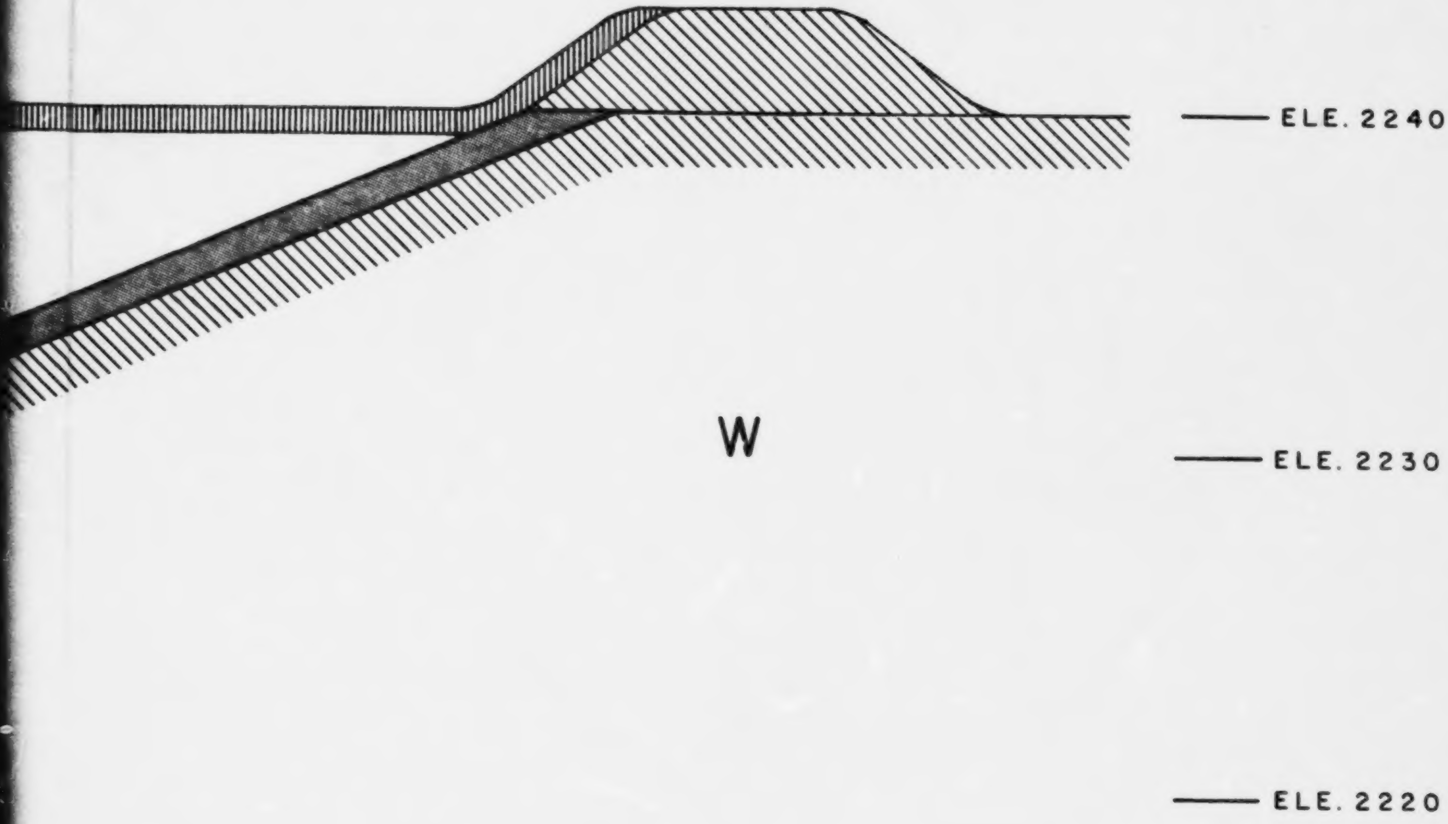
WEL

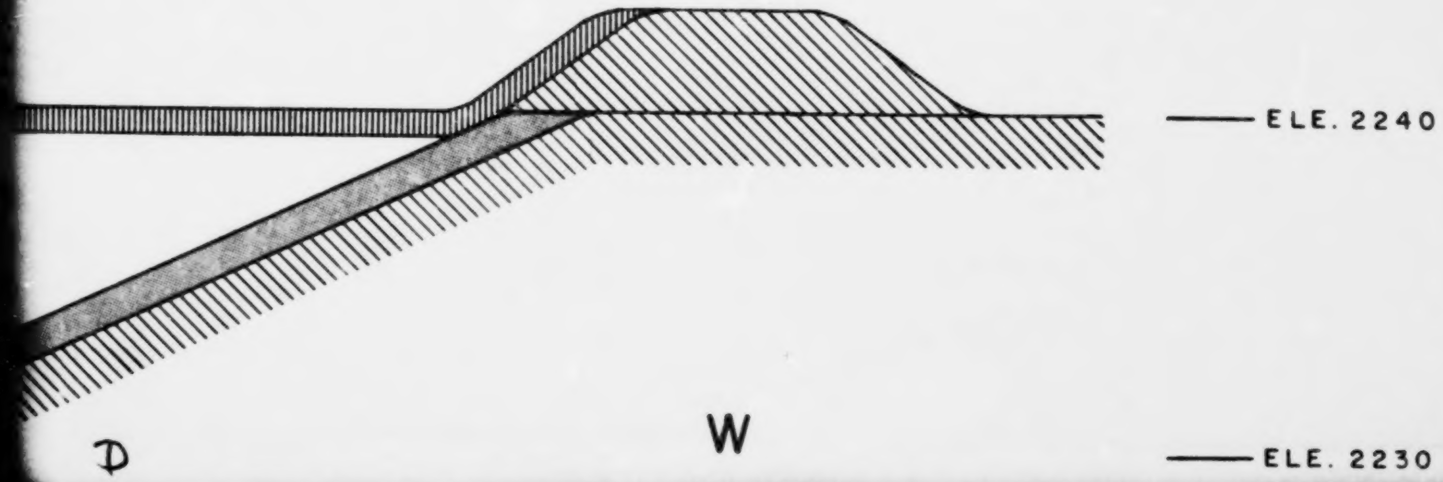

3 L
3 S
6 L
6 S
B
9 L
9 S

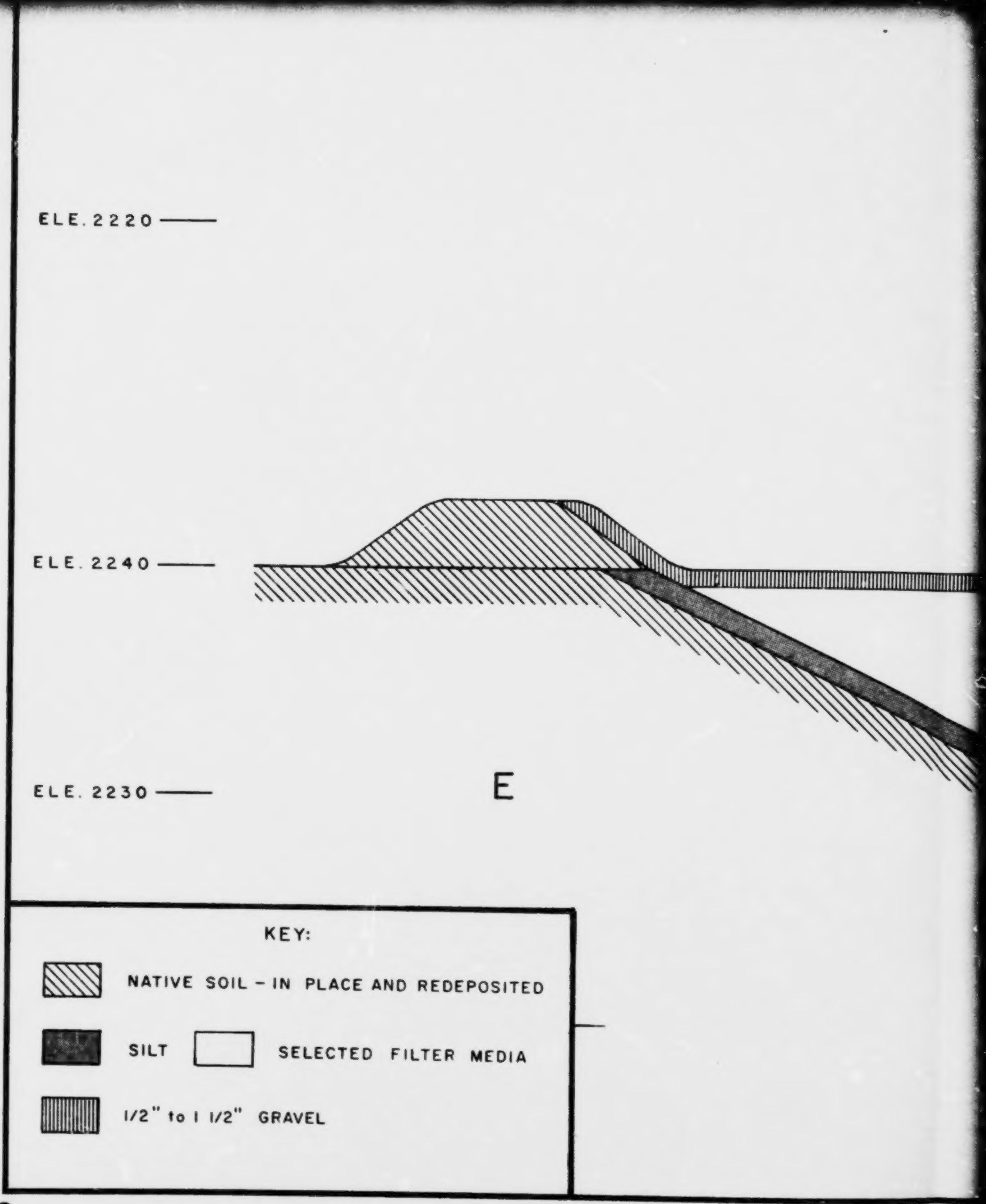

3 S
3 L
6 S
6 L
9 S
9 L
12 S
12 L
15 S

ELL 1

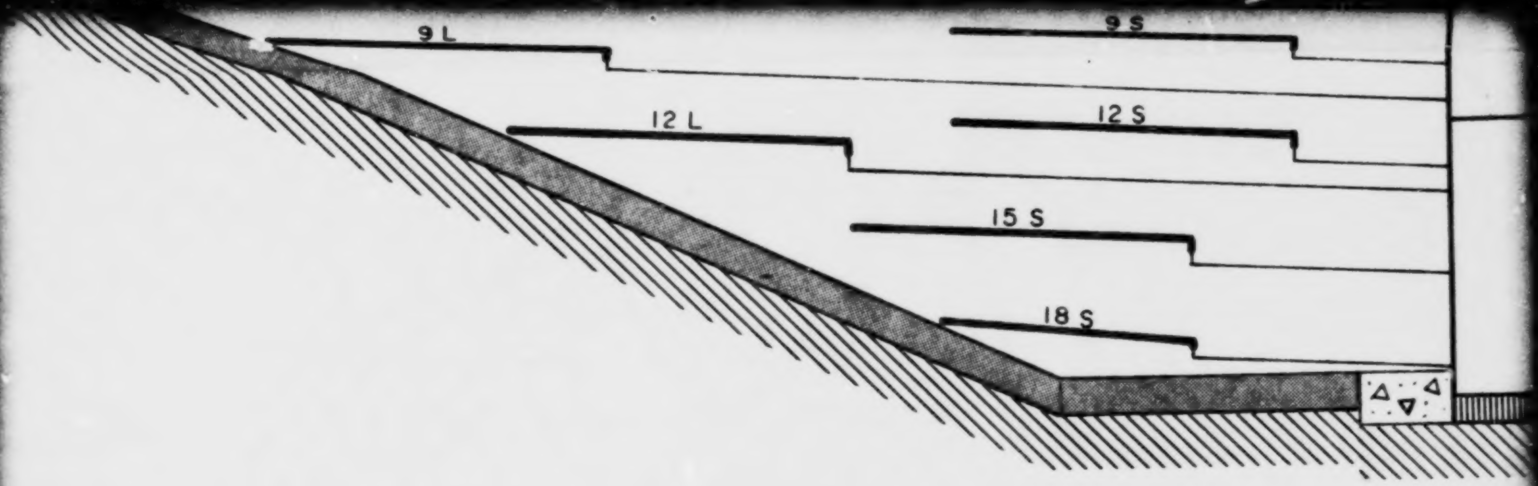

3 S
3 L
6 S
6 L
9 S
9 L
C


ELE. 2240
W
ELE. 2230
ELE. 2220

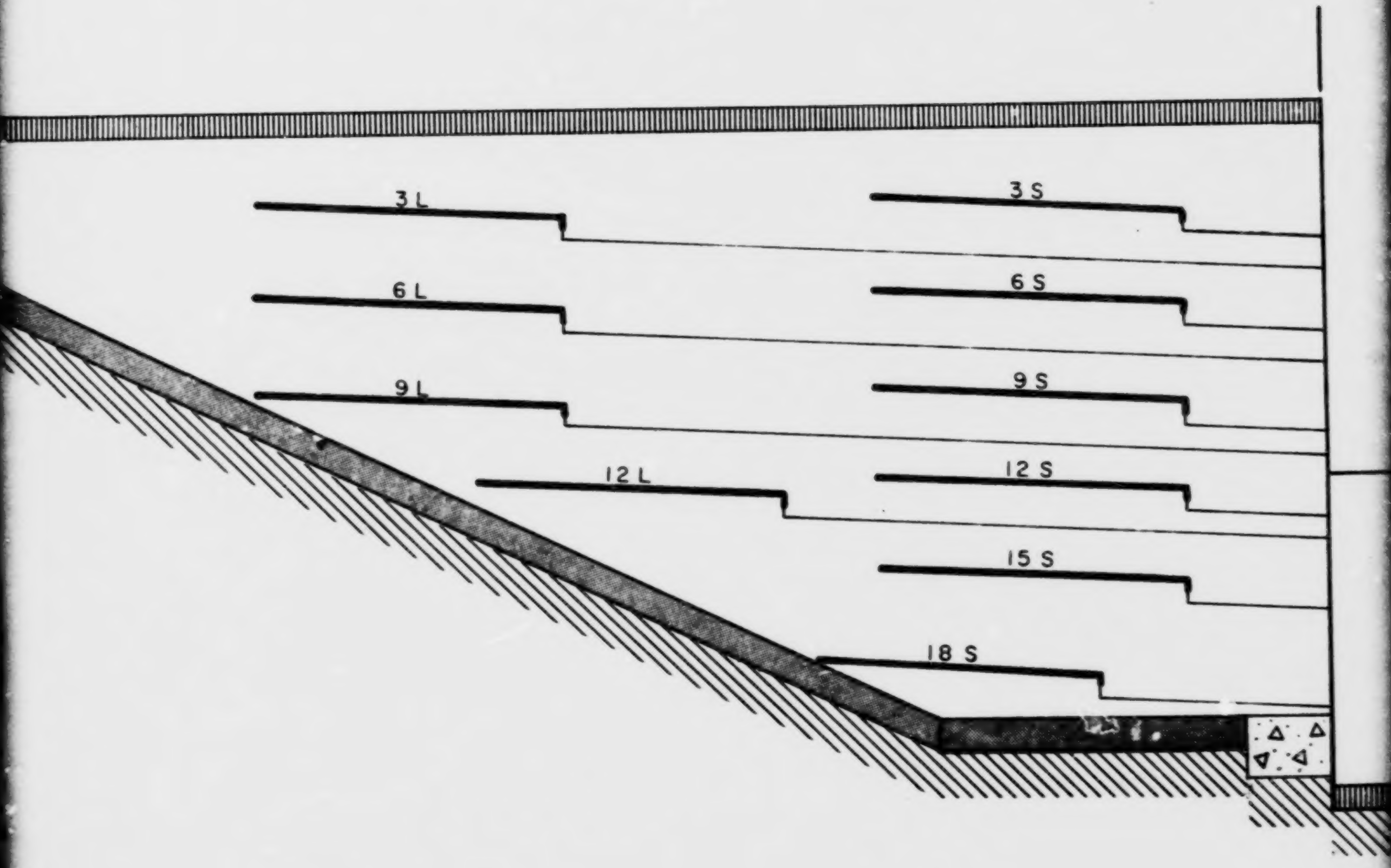

ELE. 2240
W
D
ELE. 2230


ELE. 2220
ELE. 2240
ELE. 2230
E
KEY:
▨ NATIVE SOIL - IN PLACE AND REDEPOSITED
■ SILT
☐ SELECTED FILTER MEDIA
▥ 1/2" to 1 1/2" GRAVEL

D

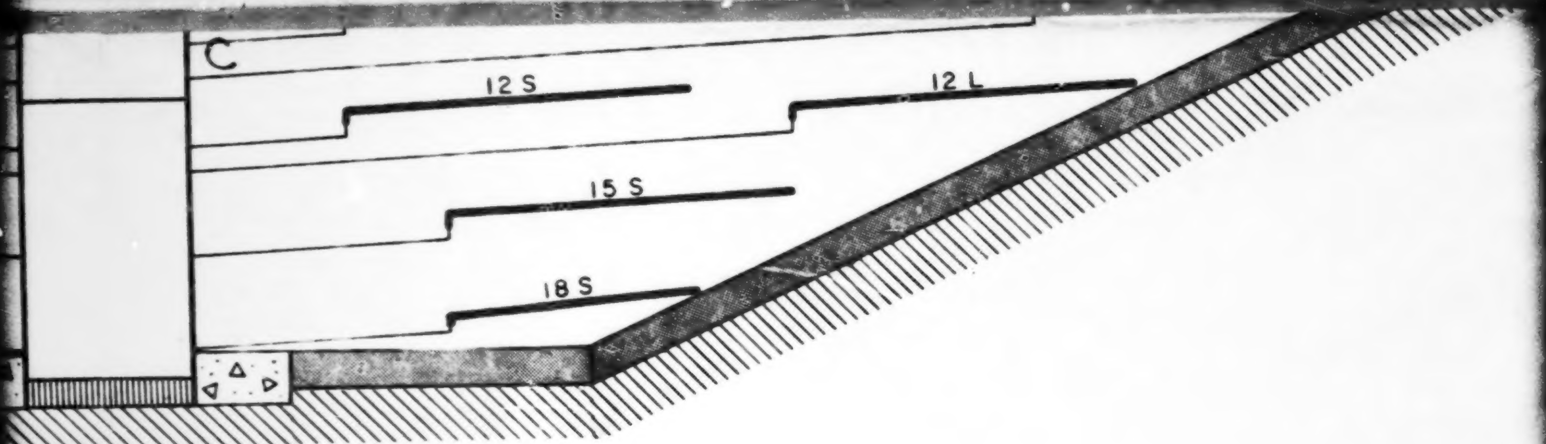

9 L
9 S
12 L
12 S
15 S
18 S

WEL

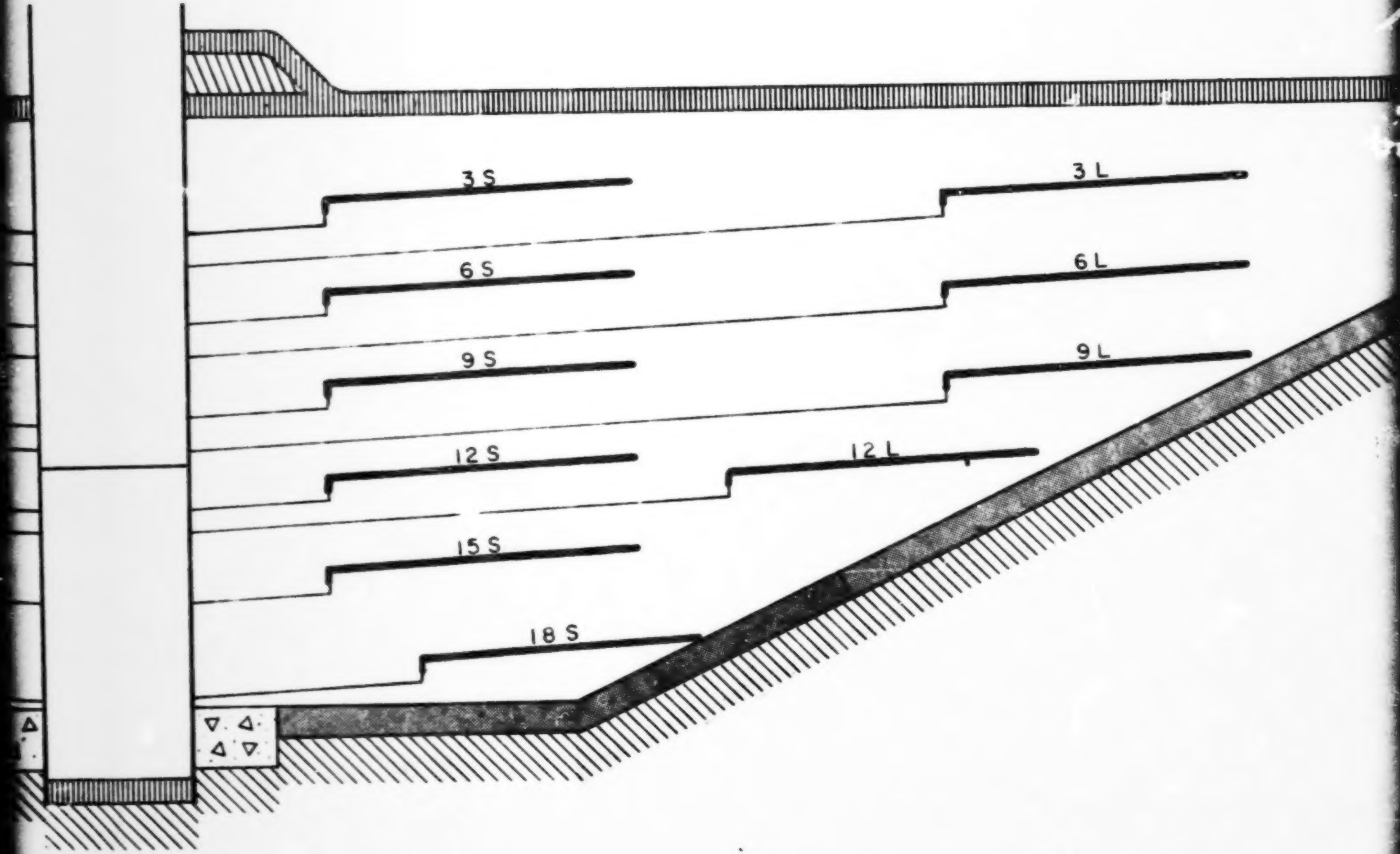

3 L
3 S
6 L
6 S
9 L
9 S
12 L
12 S
15 S
18 S

WE

E


C
12 S
12 L
15 S
18 S

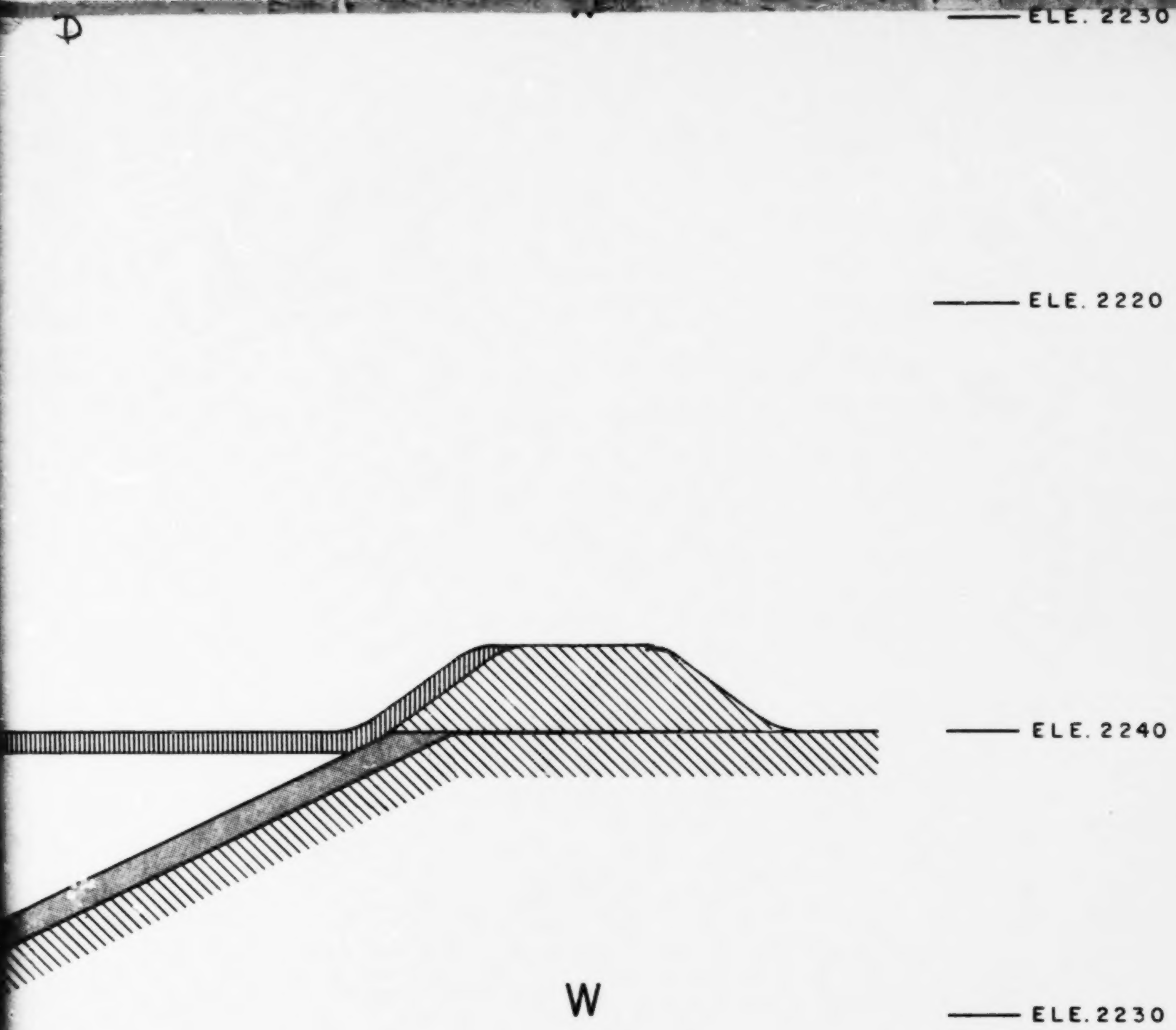
WELL 2


3 S
3 L
6 S
6 L
9 S
9 L
12 S
12 L
15 S
18 S

WELL 3

F

D


ELE. 2230
ELE. 2220
ELE. 2240
W
ELE. 2230

WPD 108-01-65

CITY OF TUCSON WATER DEPT.

TUCSON WASTEWATER RECLAMATION PROJECT

PILOT FILTER – AS BUILTS
ELEVATIONS AT SAMPLING WELLS 1, 2 AND 3

DATE: JULY 1966	DRAWN BY W.T.S.	PLAN NO. PLATE NO. 7
SCALE: 1" = 5'	CHECKED BY G. D.	SHEET OF

6